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Transforming the South Carolina Botanical Garden

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TRANSFORMING THE SOUTH CAROLINA BOTANICAL GARDEN

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ABSTRACT

This dissertation addresses the question of how to transform a small to mid-sized public garden into a botanical garden capable of making a significant contribution to science. Botanical gardens have certain features that distinguish them from pleasure gardens and public parks. These include a scientific basis for collections, an emphasis on recording data on the plants in the collection, exchanging plant materials and data with other botanical gardens, and providing educational information to visitors. Gardens often have several missions, including conservation of rare and endangered species, botanical and ecological research, and involving the public through citizen science. I describe my work with the South Carolina Botanical Garden (SCBG), in which I considered ways to make the garden more effective at research and conservation, to increase the SCBG's interaction with Clemson University and the local community, to make the garden more visible to the larger world, and to integrate the garden into the worldwide network of botanical gardens and arboreta. This work includes revising SCBG's curatorial practices and policies with a view to joining a national botanical garden conservation network, involving students in scientific collection-building through a hands-on plant collection class, increasing SCBG's visibility and scholarly presence through a project that digitized and analyzed a historic plant collection, and examining the role of laws in guiding botanical gardens' conservation efforts.

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INTRODUCTION – A CASE STUDY

What good is a botanical garden? Of what use is an herbarium? Why should there be small botanical gardens when there are big ones?

How can a small to medium sized garden be a valuable participant in the larger world of conservation and research within the BG community? How can a garden such as the South Carolina Botanical Garden survive, become and remain relevant, and succeed?

The South Carolina Botanical Garden is both large and small. It is large in physical size, with 297 acres of land. It is small in staff and budget. It has a large existing collection of over 11,000 accessions and is currently building a vast living collection of South Carolina native plants, which are being planted in ecologically appropriate settings. Under a new director, it has embarked on a transformation at a time when botanic gardens around the world are refining their missions and practices, working to become scientific institutions in addition to the pleasure gardens many have been.

For my dissertation, I have created an intellectual model for the garden as it moves forward. I have looked at policy, prioritization, and procedure; capacity building through technology and non-traditional human resources (in this case, students); and approaches to make grand impacts that extend beyond the garden gates through collaboration and doing things that SCBG is uniquely poised to do. My model takes advantage of modern technology to make curation both easy and inexpensive for the institution. The SCBG has now been recognized a true scientific botanical garden with a permanent collection deliberately designed to showcase and conserve the most important plant species, that uses best practices in data management, that is set up to perform research at all levels, from undergraduate and citizen science initiatives to high-level university faculty research, and that is engaged with the international community of botanic gardens and arboreta.

STRENGTHS AND WEAKNESSES

The SCBG has some excellent attributes: it is very large (297 acres); it is in a climate zone that is excellent for growing many plant species (USDA Plant Hardiness Zone 8a); and it is part of a major research university with many faculty and students trained in the horticultural techniques necessary for maintaining a botanical garden and in the scientific techniques needed to exploit the garden's resources. The garden already houses several collections of valuable taxa, including *Magnolia*, *Acer*, and *Ilex*. As of 2011, the SCBG was ripe for being remade in accordance with current curatorial practices.

Strengths of the SCBG

1. Large size – 297 acres, almost all readily accessed and all easily cultivated.
2. Good climate zone (USDA Zone 8), i.e. a climate without a long harsh winter, in which a number of different plant species can thrive.
3. Region of high biodiversity, near wild land with native plants, which are a good source of wild material for the living collection.

4. Proximity to experts such as Dick Figlar (magnolias) and Tom Goforth (ferns).
5. Enthusiastic volunteers.
6. A major research university as its host, with a strong horticulture/biology program.

Weaknesses of the SCBG

1. Small staff – currently 4 full-time employees.
2. No curator/recorder to focus primarily on collection development and data management.
3. An inventory in disarray as of 2010
4. No historic living collections policy or collection development plan, resulting in a collection that has arisen according to the whims of previous personnel, without consistent documentation of provenance.
5. Small budget (The budget for the academic year 2010-2011 was $1,171,770.35, which includes staff salaries, educational programs, and general maintenance).
6. Limited irrigation.

Some of the strengths make up for weaknesses – a good climate and large body of free labor can help compensate for a small staff (although using volunteers requires active coordination by staff members). Other weaknesses can be solved with ingenuity and prioritization – if there is limited time for curation, then we must use technology to make the job as efficient as possible. This has forced us to be creative in ways that larger gardens do not have to be, and possibly to create solutions that better funded gardens would not have to consider.

CAN SCBG MEASURE UP?

The international organization Botanic Gardens Conservation International (BGCI) lists several criteria that most botanic gardens meet wholly or partially ("BGCI" 2013):

1. some degree of permanence
2. a scientific basis for collections
3. scientific documentation and labeling of collections including information about origins if wild
4. monitoring plants in collections
5. exchanging seeds, plant materials, and information with other institutions
6. engaging in scientific or horticultural research on plants in collections and in herbaria
7. open to the public and providing information to visitors.

When Dr. Patrick McMillan took over as director in October, 2010, the South Carolina Botanical Garden (SCBG) met wholly criteria 1 and 7. It partially met 3 and 4, though it lacked information on most plant origins and did not have a systematic plant monitoring plan or the resources needed to monitor all collections diligently. Because the garden was historically focused primarily on growing cultivated horticultural species for the pleasure of visitors, most current collections were not developed primarily as scientific or conservation resources, but could with effort be repurposed as such. The garden was beginning to collaborate with other institutions such as the North American Plant Collections Consortium (NAPCC).

TRANSFORMING THE GARDEN

The chapters of this dissertation consider various aspects of botanic garden organization and research. I address the following problems:

1. Defining a botanical garden. What sort of work do botanical gardens to distinguish themselves from public parks?
2. Curation. How can a garden with relatively poor curatorial practices and limited financial and human resources rapidly and inexpensively fix its curation of living collections?
3. Student/citizen involvement and outreach. How can a garden attached to a university involve citizens in a way that both benefits the garden and provides a valuable experience for the citizens?
4. Research and scholarship. How can a garden use collections and collections data for research and scholarship? What can a botanical garden do to increase its visibility in the world and to make use of the data available to it?
5. Plant conservation. How can the world's botanical gardens improve their conservation of rare and endangered plants?

Obviously these are all large problems, and each of them has many possible solutions. This dissertation describes several ways in which SCBG has addressed these problems with its available resources, placing itself so that it is prepared to expand this work if greater resources become available in the future.

Chapter 1 is an introduction to botanical gardens and a survey of current literature. It describes the work that botanic gardens do today, including new avenues of research and networks of gardens and plant conservation associations.

Chapter 2 focuses on curation, and describes the process by which the SCBG reinvented its curatorial practices by taking advantage of newly developed and readily available technologies. As of 2013, SCBG can update its plant records in the field – essential if it is to keep a vast amount of data in order with few employees. The internet, portable tablet computers, and digital cameras equipped with GPS sensors make it possible for the SCBG's staff to compile accurate scientific data much more rapidly and inexpensively than was possible even five years ago. This work is presented in the context of SCBG's efforts to meet another criterion of botanical gardens: joining a national plant conservation network.

Chapter 3 addresses student involvement through a description of an undergraduate Creative Inquiry course. In this course, Dr. Jeff Adelberg and I took students out into the field to collect plants for the garden following standard scientific practices. We collected plants for the cove forest section of Dr. McMillan's newly designed natural heritage garden, took GPS readings of the plants in their wild setting, made herbarium vouchers, and saw the plants through accessioning to the point of planting them in the garden. The students also collected data for a national citizen science project. This course could serve as a case-study of a project that serves as both a learning experience for undergraduate students and a means of enhancing the garden's collection.

Chapter 4 is a description of one way of increasing a garden's scholarly and research presence, in this case by using historic collections and virtual space. It describes the work Dr. McMillan and I have done with the herbarium collections of Mark Catesby, collected in Carolina about 290 years ago and housed in the United Kingdom since the 1720s, and the digital Botanica Caroliniana project. This chapter considers the value of historical specimens and digital images thereof, and the importance of open access to scientific materials, and increasing the impact of a botanical garden as a source of digital information.

Chapter 5 focuses on one aspect of botanical gardens' work with plant conservation: the U.S. and international garden community's response to the United Nations Convention on Biological Diversity (CBD). The American public garden community would like to comply with the requirements of the CBD, partly as a way of showing goodwill toward international partners, but no one is quite sure what that compliance means. I argue that the U.S. garden community should attempt to keep the sharing of genetic material as liberal as possible and not to impose unnecessary restrictions on the movements of plants.

This dissertation illustrates several ways in which SCBG has proven itself a scientific institution worthy of the name “botanical garden.” It now has a living collections policy that has served as the basis for building a new collection: the Natural Heritage Garden. Its staff can maintain good data on the plants, including provenance, using technology that allows for rapid field checks and georeferencing. It has joined a national plant conservation network in order to help coordinate the conservation of rare taxa on a regional basis. Dr. McMillan and I have engaged in an international collaboration to publish and analyze an important set of historical botanical data relevant to this region. I have participated in a national effort to clarify the role of laws in botanical garden plant conservation.

Throughout this dissertation, I emphasize the importance of data sharing, easy access to all types of information, and low barriers to entry. Restrictive policies at all levels, from curation to publication to plant sharing, serve mainly to obstruct the free flow of scientific information and to prevent smaller institutions from realizing their full potential. Gardens such as the SCBG have a great deal to offer and are entirely capable of collaborating with other garden collections, but only if there are no unnecessary restrictions to that collaboration.

CHAPTER 1:

WHAT ARE BOTANICAL GARDENS? A LITERATURE SURVEY

Botanical gardens and arboreta are museums of plant life, collections-based institutions similar to natural history museums, zoos, and aquariums. While most botanic gardens function as public parks and pleasure gardens, they are distinguished from those institutions by their additional scientific, research, and conservation missions. There are some 2500 botanic gardens around the world, including over 350 in North America, over 500 in Europe, and over 200 in East and Southeast Asia, most of those in China and India ("BGCI" 2013). (I use the terms "botanical garden" and "botanic garden" interchangeably; both terms are in common use in the field and they mean the same thing.)

Botanic gardens contain "living collections," groups of plants grown for particular purposes. Common organizing principles for collections include geography, taxonomy, ecology, conservation status, or themes such as medicinal plants, crops, butterfly gardens, or carnivorous plants. Collections can be permanent or temporary, and can be used both to showcase plant diversity and for specific research or educational purposes (Dosmann 2006, "BGCI" 2013).

Botanic gardens are popular tourist destinations. Visits to gardens open to the public have been a popular activity since the 17th century in the UK. The practice started as visits to private gardens attached to country houses owned by the wealthy and gradually developed into a leisure activity enjoyed by all classes (Connell 2005). Visitors come to botanic gardens seeking many things, but tranquility and a nice environment top lists of motivations (Connell 2004).

Many gardens today have added education and biodiversity conservation to their missions that have developed out of living collections and herbaria. In recent years gardens have started to branch out into research on *ex situ* conservation, ecological studies, phenology, anatomy and physiology, assisted migration, and comparative genetics (Donaldson 2009a, Dosmann 2006, Primack and Miller-Rushing 2009, Jalili et al. 2010, Pyke and Ehrlich 2010). Botanic gardens also work to record and preserve traditional knowledge about plant use in indigenous communities ("BGCI" 2013).

The world's botanical gardens are collectively working to make their collections and their work relevant to a modern high-tech world facing a biodiversity crisis, digitizing their records and saving more information about the plants in their collections. Natural history collections such as botanical gardens and their associated herbaria are proving useful for many kinds of research – ecology, environmental science, climate change, genetics – as well as for commercial plant breeding and crop development (Pyke and Ehrlich 2010).

INCREASING RELEVANCE – RESEARCH IN BOTANIC GARDENS

As institutions that are both expensive to run and highly dependent on public funding and private donations, botanic gardens must constantly explain why, exactly, they need money. The recreational benefits of a garden are real enough, but insufficient to justify elaborate curation and collections building. Fortunately, botanic gardens are excellent sites for various types of research and educational activities.

Types of garden research

Botanic gardens have historically focused their research efforts on taxonomy, systematics, and horticulture, with emphasis on economically important plants and medicinal plants. More recently, taxonomists have used living collections for phylogenetic studies and taxonomic interpretation. Researchers have also used living collections for multidisciplinary programs in plant conservation and for ecological studies. In recent years gardens have started to branch out into research on *ex situ* conservation, phenology, anatomy and physiology, assisted migration, and comparative genetics. Because this research has been added on top of the institutions' existing missions, the work is often idiosyncratic and multidisciplinary (Donaldson 2009a, Dosmann 2006).

Museums and botanical gardens perform three main types of research: basic, applied, and summative. Basic research could include work on taxonomy, plant biology, plant physiology, genetics, and evo-devo. Applied research includes work on propagation, invasive species control, or testing new varieties. Summative research involves the compilation and presentation of information from previous work. Gardens can do research both on their living plant collections and in natural habitats or in herbaria (MS Dosmann 2006).

Currently, only a minority of gardens are used for research. Dosmann (2006) suggests that this is because garden managers are not advocating gardens' research potential, with the result that institutions fail to see the value of gardens in this area and shift their emphasis from collections to public service. He argues that research should be a fundamental component of a garden's work, especially university gardens, that collections are in themselves an asset and a good source of centralized information, and that research will both improve collections management and keep collections relevant.

Donaldson (2009a) identifies the following areas as current strengths of botanical gardens as well as where future research should be concentrated:

1. Examining herbarium collections for information on global change and conservation planning, as well as improving data collection and information sharing among herbaria
2. Seed banking and reintroduction and restoration methods
3. Fully using living collections and growth facilities for monitoring and experimentation
4. Using citizen scientists to collect data
5. Increasing focus on ecosystem services.

For instance, gardens can be used to test the necessity of specific species on ecosystem functioning both in terms of providing useful plants such as medicines for humans and the role of plants in the restoration of degraded ecosystems (Donaldson 2009a).

Living collections are also useful for biological research. For example, a number of gardens have begun deploying their collections for research in evolution of development (evo-devo), which studies the evolutionary history and molecular basis for biological processes. This type of research requires subjects sampled from different species or ecotypes. Living collections are an ideal source for this type of plant material. Researchers have used living collections to study adaptations to elevations, latitudes, flowering patterns, leaf complexity, and gene expression (Michael Dosmann and Groover 2012). University gardens in particulare are well suited to integrating research programs into their work (Meyer et al. 2010).

Record keeping is one of the most important activities of a botanic garden. A garden, like any museum, must at the very least identify and document its holdings. Keeping records can add value to the collection by providing a body of information about plants. Gardens are potentially well placed to create large data sets; curators monitor all plants in their collections, and produce data that spans time and space. Once information is collected in a database, gardens and other institutions can easily share information with each other. Good data sets, especially long-term data sets, are particularly useful for ecological and climate change research (Jeger and Pautasso 2008). Georeferencing from provenance data can help researchers find endangered species in the wild or track their movements over the decades, and it shows what species occupy the same habitats (MS Dosmann 2006). Accurate provenance data can help develop conservation collections that represent the full range of genotypes (Rae 2010). The BGCI's International Transfer Format for

Botanic Garden Plant Records (ITF) (www.tdwg.org) is one of the international standards for botanic garden record systems ("BGCI" 2013).

Education, Outreach, and Citizen Science

Many gardens would like to get visitors more involved, to increase enthusiasm for conservation and science. Most gardens have an educational mission, at the very least labeling their plants so that visitors can identify them. There are numerous ways to develop educational programs, which is a fruitful area for research and study. For example, gardens have studied: the use of a "dragonfly awareness trail" to teach children and adults about conservation (Suh and Samways 2001); the use of films, displays, themed gardens and other landscape narratives to educate visitors more effectively (Chang, Bisgrove, and Liao 2008); the use of ethnic horticulture gardens to attract visitors from ethnic groups that do not traditionally visit botanical gardens (Steinhauer et al. 2007).

Citizen science is one area with vast opportunities for research involving collaboration with the public. The Cornell Lab of Ornithology pioneered the use of citizen scientists to collect large datasets, and has found that this method can be remarkably successful at advancing scientific knowledge while also educating the citizen scientists about the organisms and processes they are studying (Bonney et al. 2009). The general public can collect data on plant phenology, invasive species, and restoration projects. The scientific value of the data might make itself evident only after a long time, but data generated by “citizen scientists” can eventually produce large and useful data sets (Donaldson 2009a). For example, Clemson scientist Ron Johnson has recently used citizen scientist volunteers to study the effect of climate change on migration dates of ruby-throated hummingbirds (Courter et al. 2013).

Ecological research

Botanical gardens are ideally placed to do ecological research. This work can cover areas such as climate change, phenology, geographic distribution, invasive species, and adaptations to different environments. Phenological research is particularly suitable for citizen science.

Pyke and Ehrlich (2010) predict that the relevance of natural history collections would be enhanced if institutions could emphasize the ecological and environmental value of their work. There are millions of biological specimens housed in herbaria and museums around the world. Although natural history collections are primarily seen as material for research in taxonomy and systematics, support for such research declined in the second half of the 20th century even as the task of classifying world biodiversity grew much larger. Environmental and ecological research, however, increased during that period.

Collections are useful for determining some aspects of geographic distribution; revisiting collection sites can show whether a species is still there. Models of species distribution can be used to determine such phenomena as the effect of climate change on migration. Biological specimens allow researchers to examine individuals and if there are enough specimens can be used to determine aggregative properties of sampled populations as well as levels of variation within and between populations. Researchers might be able to use collections to identify evolutionary changes in morphology over space and time. Plant specimens examined in this way can provide evidence of changes in atmospheric composition or climate (Pyke and Ehrlich 2010).

Botanical gardens are well-positioned to conduct climate change research. They contain a large number of plant species growing together under common garden conditions and usually well tended. They contain ecological and taxonomic diversity that does not occur naturally. Gardens often maintain long-term records and may either maintain or have access to institutional herbaria assembled over decades, other resources that can allow researchers to investigate patterns over time. Botanic garden staff members know a great deal about their collections and their habits, and are often the first to notice that plants are growing better or worse due to changing climate. Botanic gardens are connected through research networks that make it possible to compare plants grown in many different locations (Primack and Miller-Rushing 2009, Jalili et al. 2010. See also Belinda Hawkins, Suzanne Sharrock, and Kay Havens 2008, Bisgrove and Hadley 2002).

A number of individual botanic gardens and other institutions have created phenological gardens that use standard plants in different areas in order to observe the effect of local climates on plant behavior and pollinators, sometimes using citizen volunteers to collect data (Primack and Miller-Rushing 2009). The USA National Phenology Network (www.usanpn.org) currently collects a large amount of phenological data through a network of citizens, universities and schools, government agencies, and other groups ("USA National Phenology Network" 2013). Project BudBurst (budburst.org) is another national citizen scientist phenology project; Clemson students participated in this project as part of the Creative Inquiry described in Chapter 3 ("Project BudBurst" 2013). In Europe, the International Phenological Gardens (IPG) project has studied 21 plant species planted in 89 gardens in 19 European countries and has found that over the past 30 years the growing season in Europe has increased by 11 days (Humboldt-University of Berlin 2010, Primack and Miller-Rushing 2009).

Botanical gardens are also in a good position to study invasive species. Because botanic gardens are often the result of years of collection of exotic plants, they are inadvertently in a good position to study invasive species. Garden collectors for the past two centuries have deliberately introduced, acclimatized, and cultivated foreign species for horticultural and commercial purposes; the nursery trade, humans, and other animals inadvertently spread seeds and germplasm. Hulme (2011a) has pointed out that botanical gardens have been implicated in the introduction of some of the most noxious invasive weeds in the IUCN's list. So-called "safe" alternatives to invasives may be fecund enough to invade handily (Knight, Havens, and Vitt 2011). In gardens where management has fallen off for one reason or another, invasive species may have more opportunity to spread and naturalize (Dawson et al. 2008). It may be too soon to say whether current efforts will ultimately be effective at curbing the exodus of invasive plants from garden collections (Hulme 2011b).

Invasive plants are certainly an opportunity for research that could have wide applicability. Botanic gardens can monitor their collections for invasive species by watching which introduced species tend to spread readily. This can be part of regular weed assessments, which many gardens already perform. This type of research can also be used to plan assisted migrations, in which garden managers or conservation biologists transplant poor dispersers into regions where the climate may become appropriate for them (Primack and Miller-Rushing 2009). Gardens associated with universities could use students and faculty to assess risks of invasiveness (Reichard and White 2001).

Herbaria

Donaldson (2009a) believes that herbaria are one of the areas on which botanical gardens should concentrate future research; he cites the value of herbarium collections for studying climate change and planning for conservation efforts.

Herbaria contain large numbers of specimens from plant species that are as yet undescribed. The vast majority of new species are identified only after collection in an herbarium and subsequent comparison with other representatives of the taxon; only a few new species are immediately recognized as such at the time of collection in the field. Even when there are no more living plants to collect in the wild, herbaria will still contain undescribed specimens (Bebber et al. 2010). Herbaria have recently re-discovered specimens collected by Charles Darwin during his voyage on the Beagle between 1831 and 1836 (Porter, Murrell, and Parker 2009).

Herbaria are increasingly used for climate change studies. Researchers at Kew and other British institutions have recently conducted an in-depth study of the flowering times of the orchid *Ophrys spehgodes* using herbarium specimens dating back to 1848. They found that herbarium specimens reflected the same changes in flowering time as field observations, validating the use of herbarium specimens for this type of research (Robbirt et al. 2010). Herbarium records in Phoenix, Arizona, indicate that flowering times have changed over the past century, and that there are significant differences in phenological changes between urban and non-urban areas (Neil, Landrum, and Wu 2010). Botanists in Canada have used herbarium specimens to reconstruct the flowering dates of plants collected across large areas, discovering that Coltsfoot (*Tussilago farfara* L.) blooms some 15-30 days earlier now than it did in the early 20th century (Lavoie and Lachance 2006). A recent study in Australia and New Zealand used herbarium specimens to determine whether introduced plant species have undergone rapid evolution (Buswell, Moles, and Hartley 2011). Herbarium specimens can also be useful for projects such as comparing the number of stomates on the undersides of leaves, an indication of plant populations responding to increases in CO2 concentrations by growing leaves with fewer stomates per unit area (Primack and Miller-Rushing 2009).

Researchers at Cambridge University have used herbarium specimens to study phylogenetic variation in crop landraces and the past geographic distribution of those species. Genetic data from specimens is especially useful; DNA extracted from herbarium specimens is often in an excellent state of preservation, and historic cereal specimens are widely available and cover species from all over the world (Lister, Bower, and Jones 2010). It is possible to sequence DNA from historical herbarium specimens and silica-dried specimens, making herbarium specimens useful for molecular systematic studies (Lehtonen and Christenhusz 2010).

Herbarium specimens combined with GIS techniques can be used to analyze the population structure and extinction risk of plant species known primarily from herbarium specimens (Rivers et al. 2010). Herbarium specimens have been used to identify the spatial spread of alien plants in New Zealand (Aikio, Duncan, and Hulme 2010). Researchers have begun using GIS techniques with herbarium specimens and IUCN Red List categories to assess the population structures of endangered plants (Rivers et al. 2010). Herbarium specimens have been used to identify new species of *Solanum* in Kenya, as well as determining areas of habitat loss and environmental change (Vorontsova et al. 2010). Italian researchers have successfully germinated spores taken from herbarium specimens of the fern *Osmunda regalis* (Magrini et al. 2010).

Biodiversity informatics is a major area in herbarium and botanic garden work. Researchers at the Universities of Michigan and Kansas have collaborated with a university in Barcelona to partially automate workflows for gathering specimen data from digitally imaged herbarium labels. The object of this exercise is to streamline the logistics of entering data into a database, including the addition of georeferencing data (Granzow-de la Cerda and Beach 2010).

Sustainability

Sustainability questions, including water supplies, fertilizer, compost, and drainage issues are all relevant to gardens and could be rich areas of research. University gardens could be especially useful for student projects in landscape design, hydrology, composting, sustainable development, and other related topics. For example, researchers in the Philippines have applied forestry templates to a local botanical garden to measure the sustainability of its management practices. (Andrada II and Calderon 2008)

The Sustainable Sites Initiative (http://www.sustainablesites.org/) is a partnership of the U.S. Botanic Garden, the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center at the University of Texas at Austin and several other stakeholders to create a national rating system for sustainable landscapes. The guidelines can apply to any site that will be used for public or private purposes, whether or not it contains buildings. The rating system is contained in the Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009. About 150 pilot projects are currently participating in the SITES two-year pilot program, which runs from June 2010 to June 2012. Eight percent of participating institutions are gardens or arboreta. For example, Adkins Arboretum's Native Garden Gateway in Ridgely, MD, is redesigning its main entrance and parking areas to incorporate permeable surfaces that will filter runoff through soils and vegetation, intended to serve as an example of a low-impact stormwater management system. Feedback from these projects will be used to revise the rating system and technical reference manual and to provide real-world guidelines for achieving sustainability goals ("Sustainable Sites Initiative" 2013).

BOTANIC GARDENS AND CONSERVATION

Today botanical gardens focus much of their attention on conservation of plants. Botanical gardens specialize in what is known as *ex situ* conservation, conserving species by growing them in sheltered environments away from their natural habitats. This is in contrast to *in situ* conservation, in which plants or animals are maintained in their natural habitat. *In situ* conservation is the ideal, but *ex situ* conservation is becoming more important as natural habitats disappear (Powledge 2011). Many gardens grow or preserve as seeds *ex situ* collections in the hope of preserving species endangered or extinct in the wild, or as a complement to *in situ* preservation (Li and Pritchard 2009). BGCI predicts that botanic gardens may be important sources of plant material in the near future as ecosystems must be stocked with new species to combat climate change ("BGCI" 2013). Botanical gardens and arboreta are also actively and personally involved in the drafting and application of national and international laws that regulate the collection and conservation of plants.

Plants under Threat

BGCI estimates that there are about 400,000 species of plants in the world and that one in five of these are threatened with extinction. Threats include habitat loss and degradation, competition with introduced invasive species, overexploitation, and climate change ("BGCI" 2013). As of July, 2012, the U.S. Fish and Wildlife Service listed 794 plants and lichens as endangered or threatened in the U.S ("USFWS" 2013). The IUCN Red List included 14,582 entries of plants assessed at least Vulnerable ("IUCN" 2013).

Many plant species would not exist at all today if gardeners had not preserved them. The native American tree *Franklinia alatamaha* survives thanks to John and William Bartram, who discovered the tree in Georgia in 1765 and began propagating it shortly before it disappeared completely from the wild around 1800 (Del Tredici 2005). The spectacular Dove Tree, *Davidia involucrata,* arrived in European and North America gardens through sheer luck; in 1899 plant collector E.H. Wilson went to China seeking the fabled tree only to discover that the one known specimen had been cut down for lumber. He searched far and wide in the woods to find a few more trees growing wild and thus managed to collect enough seed to introduce the tree to the nursery trade (Schulhof 2005).

Many plant taxa are extinct in the wild and exist only because of the work of botanical gardens, and not because of their ornamental traits, as described above. For example, *Sophora toromiro*, a small tree from Easter Island, went extinct in its natural habitat but was preserved for reintroduction by the Bonn University Botanical Garden (Maunder et al. 2000). The Royal Botanic Gardens, Kew, has collaborated with the Seychelles Botanic Garden to breed and re-establish *Rothmannia annae*, a plant native to the Seychelles that is nearly extinct in its home environment ("IPEN" 2013). *Kokia cookei*, a tree endemic to Molokai, Hawaii, went extinct in the wild in 1918 but has been cultivated in botanical gardens since then; as of 2008, it was growing at Waimea Audubon, Lyon Arboretum, Volcano Rare Plant Facility, and the National Tropical Botanical Garden ("USFWS" 2013). The last known wild *Cyanea pinnatifida*, endemic to Oahu, died in 2001, leaving its cultivated progeny in the Lyon Arboretum and the National Tropical Botanical Garden ("IUCN" 2013). The Hawaiian plant *Cyanea truncata* was thought to be extinct after the last known individual died in the 1980s. Subsequent surveys discovered a few more wild plants, three of which survived as of 2006, and which provided genetic material that botanists have used to propagate more plants and outplant them into a protected habitat. The state of Hawaii's Genetic Safety New Program and the Lyon Arboretum were maintaining seeds and tissue samples that could be used to propagate more plants in the future ("USFWS" 2013). These are all examples of serendipitous conservation collections, collections that were created for other purposes but turned out to have conservation value as well. (see Heywood 2010).

Preserving Genetic Diversity

Like zoos with captive breeding programs, botanical gardens face several problems associated with *ex situ* collection, including small population sizes, genetic drift, spontaneous hybridization, and inbreeding depression (Volis and Blecher 2010). Botanical gardens working in *ex situ* conservation and hoping to re-establish wild populations must ensure that *ex situ* collections contain as much genetic diversity as possible (Donaldson 2009a).

There are several ways to do this. One is to store seeds, which are small and genetically unique. Some botanic gardens have invested in cold-storage technology and cryopreservation, which may make their seeds, embryos, and tissues viable for many years ("BGCI" 2013). The USDA runs the National Plant Germplasm System (NPGS), a cooperative effort by state, federal, and private organizations to preserve the genetic diversity of plants and facilitate the breeding of new crop varieties ("GRIN NPGS" 2013). Some regional networks of seed banks share materials with one another. The Kew Seed Bank has embarked on the Millennium Seed Bank Project to collect and conserve seed from most UK species and from 10% of the world's flowering plants ("BGCI" 2013).

But not all seeds can be stored, which makes the conservation of living plants the only alternative. Some plants produce "orthodox" seeds, which can be dried survive for months or even years without losing viability; these seeds are adapted to waiting long periods until environmental conditions are suitable for them to germinate. Others produce "recalcitrant" seeds, which cannot survive drying or low temperatures and typically germinate quickly in the wild (Hartmann and Kester 2001) Seed storage techniques are currently not always adequate for all types of seeds. Cryopreservation might help preserve some seeds that do not respond well to current techniques; work in this area is fairly new and ongoing (Li and Pritchard 2009). In order to maximize the value of seed collections, researchers need to learn more about how to store individual seeds and to help them germinate when needed. This is especially important in the case of plants where only a few seeds have been stored, making it that much more crucial that germination techniques maximize the chance of success (Godefroid, Van de Vyver, and Vanderborght 2010).

The other main way to preserve genetic diversity is to collect plant material from as wide a variety of wild sources as possible and then to grow it in the living collections of a number of different institutions that can then share germplasm for breeding and reintroduction programs (Rae 2010). Plants in living collections can furnish genetic material as seeds, with unique genotypes, or as tissue, which produces clones. *Ex situ* plants can also be studied as organisms that respond to natural stimuli such as climate change.

Does *Ex Situ* Collection Really Work?

Some critics believe that *ex situ* collection is of limited conservation value at best (Swarts and Dixon 2009). *Ex situ* collections could be a source of genetic material for reintroductions, but reintroduction is not always feasible. Preserving single specimens of nearly extinct taxa might be valuable academically or as a curiosity, but may have limited practical value if a species has no hope of returning to the wild in large numbers.

Botanists worry that botanic gardens do not represent a wide array of genotypes; many *ex situ* collections of rare and endangered plants consist of very few individuals taken from one site only, and collection is often biased by ease, with collectors procuring the most accessible plants instead of getting a wider sampling of individuals from a wild population (Samain and Cires 2012). Genetic diversity can decrease through genetic drift, i.e. loss of genetic diversity in small populations over several generations (Enßlin, Sandner, and Matthies 2010) and hybridization, i.e. interbreeding of related species, resulting in offspring that are not members of either parent species (Zhang et al. 2010); both genetic drift and hybridization are natural processes that may be unavoidable when dealing with living organisms that reproduce freely. Researchers have found large genetic differences between *ex situ* collections and their wild counterparts after 20 to 36 years of separation, with *ex situ* collections losing genetic diversity in cultivation (Lauterbach, Burkart, and Gemeinholzer 2012). Tree species may not be best conserved in botanic gardens, which are too small to house many individuals of the same species (Oldfield 2010). Using a study of the relict genus *Zelkova* as a model, researchers found that the most acutely threatened species are not the most represented in collections, only a small percentage of plant material is of known wild provenance (less than 20% in the case of *Zelkova*), and most collections of particular taxa within individual botanic gardens are very small, between one and ten individuals (Kozlowski et al. 2012).

Gardens have responded to criticisms about their effectiveness by revising their collections policies to focus on high-priority taxa, maintaining better data and sharing it with other institutions and conservation networks, and integrating *in situ* with *ex situ* preservation (Namoff et al. 2010, Maunder, Higgens, and Culham 2001). Techniques such as adequate sampling at time of collection, collecting from large populations, and using near-natural cultivation to allow generation overlap and interspecific competition can improve genetic diversity within collections (Lauterbach, Burkart, and Gemeinholzer 2012). Gardens are beginning to coordinate conservation efforts among institutions and to perform large scale genetic studies to verify provenance (Kozlowski et al. 2012). BGCI has sponsored research to verify the genetic diversity of garden collections, which will lead to better conservation in the future (Samain and Cires 2012).

Israeli researchers have recently begun experimenting with quasi *in situ* collections, i.e. growing *ex situ* collections in a natural or semi-natural environment that replicates as closely as possible the conditions in which the plants grow in the wild. This approach might avoid some of the problems associated with normal *ex situ* cultivation, such as small population sizes, genetic drift, spontaneous hybridization, and inbreeding depression (Volis and Blecher 2010). The Royal Botanic Garden, Edinburgh has done similar work with its conifer conservation program, dedicating plantations to single populations so they can outcross safely (Rae 2010).

In order for botanic gardens to succeed at this effort, they must be able to easily/lawfully/ethically collect wild plant material, including seeds, cuttings, and whole plants. They must be able to visit as wide a range of sites as possible, and to take samplings from as many populations as they can. Widespread and free sharing of plant material among institutions would also increase the number of plants that could be grown. Multi-institutional conservation groups might be one solution; the Center for Plant Conservation, for example, exists to do just this ("CPC" 2013).

BOTANICAL GARDEN NETWORKS

Botanical gardens' efforts at conservation have been considerably enhanced by the creation of worldwide networks of gardens, which share information and genetic material and can collaborate to best distribute limited resources. The worldwide botanic garden network, with more than 2500 sites worldwide, is the single largest plant conservation network in existence. Botanic gardens around the world cultivate more 150,000 plant taxa in their living collections, including about 12,000 taxa that are extinct in the wild or nearly so ("BGCI" 2013).

There is a long tradition of sharing of botanical materials, dating from the days of explorers who carried plants from continent to continent in the 17th through 19th centuries. Botanical gardens typically hold highly international collections of plants. Many ornamental plants popular in American and European gardens are native to Asia – some of the most popular types of azaleas, camellias, and various magnolias came from

China and Japan, many of them over one hundred years ago. As a consequence of long-ago plant movements, gardens in the West house taxa that are endangered in the East. Even small unknown gardens can hold rare and endangered species, sometimes without even realizing it.

National Networks

Modern technology and communications have made it easier to set up deliberate exchange and collaboration programs. Within the United States, several organizations coordinate plant conservation efforts.

The American Public Gardens Association (APGA), is a group of botanical gardens dedicated to information sharing, networking, public awareness, and research ("APGA" 2013).

The North American Plants Collections Consortium (NAPCC) is a collaboration between APGA and USDA-NPGS, coordinating a continent-wide approach to managing plant collections and preserving plant germplasm. Members share information and germplasm in order to more efficiently conserve important plant groups and facilitate scientific research and breeding . The NAPCC organizes multi-institutional conservation networks to coordinate the cultivation of certain taxa among numerous gardens ("NAPCC" 2013).

The Center for Plant Conservation (CPC), housed at the Missouri Botanical Garden in St. Louis, is dedicated to preventing the extinction of native U.S. plants. It maintains informational profiles on numerous endangered and threatened plant species and contracts with participating botanic gardens to serve as custodians of particular taxa ("CPC" 2013).

Major botanic gardens such as Arnold Arboretum of Harvard University, the Missouri Botanical Garden, and the National Arboretum in Washington, D.C., also participate in collaborative and individual research and conservation initiatives.

BGCI

Botanic Gardens Conservation International (BGCI), established in 1987 by the International Union for the Conservation of Nature (IUCN), is the leading international organization working to save endangered plants. Its headquarters are in London and it has regional offices in the USA, Kenya, Singapore, and China. BGCI is registered as a UK charity and receives support from the Royal Botanic Garden, Kew, and Royal Botanic Garden, Edinburgh. It is a member organization, but non-members can participate in its activities and benefit from its information (P. S. Wyse Jackson and Sutherland 2000).

BGCI's goals are to reverse the loss of key plant species and their habitats, preserve threatened plants in *ex situ* collections, promote the conservation and sustainable use of plants important to human life, and study the effect of climate change on plants ("BGCI" 2013). BGCI aims to create partnerships and alliances among institutions to create a united approach to plant conservation. (P. S. Wyse Jackson and Sutherland 2000). BGCI was instrumental in developing the Global Strategy for Plant Conservation to the

Convention on Biological Diversity in 2002 and in revising the GSPS for 2011-2020 ("BGCI" 2013).

BGCI invites gardens to upload their collections information to the PlantSearch database. This is part of the organization's effort to document the threatened species in *ex situ* collections around the world. This is also an easy way for a garden to learn the conservation value of its collection because the PlantSearch engine will identify all threatened species. At the moment, no one knows exactly how many threatened plants are held in *ex situ* collections. The only way to find out is for as many botanic gardens as possible to contribute information on their collections and to keep that information updated ("BGCI" 2013).

BGCI has recently published a comprehensive report on the U.S.' botanical strengths and weaknesses and has called for more education in botanical fields (Kramer, Zorn-Arnold, and Havens 2010). In 2010 BGCI also published a lengthy report on the role of botanic gardens. The authors concluded that most botanic gardens need to redefine their values and missions to combine environmental and social goals. They noted that botanic gardens are well-placed to study and raise awareness of climate change, but that few gardens are doing so. Once a garden has redefined its mission, it can increase its communication with the wider world and advocacy for plants (Dodd and Jones 2010).

CONCLUSION

The botanical garden world is in the process of reinventing itself. Gardens everywhere face a practical question: in a high-tech world facing a biodiversity crisis, what can botanical gardens offer? How can they make themselves relevant?

Gardens have produced some answers to those questions, a few of which I have described in this chapter. Gardens can exploit and develop their collections with an eye toward many kinds of research. Gardens are in a position to produce findings on a variety of topics: plant physiology, genetics, ecology, climate change, horticultural suitability, entomology, education, sustainability, and many others. This research can include students and citizen scientists.

At SCBG, research projects include testing seed-grown *Shortia galacifolia* for vigor; trialing plants from Asia and Mexico for viability in our climate; and assessing the hardiness of a collection of hydrangeas in the absence of irrigation. Garrett Ridge, a graduate student in the Plant and Environmental Science program at Clemson, sought out the garden’s *Rhododendron catawbiense* to use as leaf baits for his research on *Phytophthora*. Another graduate student, Kate Cummings, in 2012 was developing a project to study folk knowledge connected to heirloom seeds and develop their propagation in the garden. My students in Hort 408 in Spring 2012 used the garden’s collections for phonological observations for the national citizen science initiative Project Budburst (“Project BudBurst” 2013).

There is the potential for much more. By making their gardens available to researchers and by inventing creative ways to study their own collections, botanical gardens can contribute to scientific knowledge and involve the public in ways that make their relevance obvious.

CHAPTER 2: CURATION

Curation is the heart of any natural history collection. Curation in this context begins with simple caretaking, but extends to the philosophy guiding collections development and operational decisions, inventory and databases, mapping, landscape management, and the sharing of data and materials. BGCI's criteria for identifying botanical gardens include the scientific documentation and labeling of collections, maintaining information about the origins of plants, the monitoring of plants in collections, and the sharing of information with other institutions. A garden without curation is simply a pleasure garden. A garden with curation is a botanical garden.

Curation requires attention to detail, but at a garden with a small staff it cannot be too complicated. At a garden with a small budget, it cannot be expensive. This chapter describes how the SCBG staff and I revised the garden's curatorial practices to bring them in line with industry standards by taking advantage of new technologies that make quick work of data organization and mapping. This work took place in the context of SCBG's efforts to meet another criterion of botanical gardens: joining a national plant conservation network.

INTRODUCTION: CURATION IN GENERAL

Hohn (2008) describes a botanical garden as a living museum. Like other museums, botanical gardens must follow the practices common to all museums and other collections based institutions. A collection in this context is a group of objects brought together to fulfill the garden's stated purpose. A garden can have many different collections – roses, maples, native plants, educational plantings.

Curatorial practices focus on several aspects of maintaining collections. A garden might have policies to govern the building and management of collections. It will document its collections; this is necessary both for daily maintenance and for research, which requires good data. Therefore policies and data management make up the heart of curation in this context.

In most museums, curation is the responsibility of a curator. Hohn defines a botanical garden curator thus: "a botanical garden staff member responsible for the acquisition, documentation, and preservation of collections for current and future research, conservation, educational, and exhibition/display needs." Not every garden has a single employee devoted exclusively to this role, but every one needs at least some staff attention to curation.

Living Collections Policy

A botanical garden needs a living collections policy based on the garden's mission that defines both long and short-term goals of collection building. A sound policy will ensure that every acquisition has a value that fits with the collections philosophy and that every plant in the garden is there for a reason. It also provides the director with justification for deaccessioning plants that do not fit with its collections goals. Without a policy to define the collection, accessions can accumulate without any clear purpose, diluting the garden's mission and diverting resources from important collections (MS Dosmann 2006).

A good collection is the basis for garden research. A thoughtfully designed collection can provide fodder for research that may not have been anticipated when the collection is created; for example, gardens form intact ecosystems that can be studied in various ways, and one never knows what plant diseases may present themselves as research topics. A clearly defined collection can also be useful in collaborative research with other institutions (MS Dosmann 2006).

The Arnold Arboretum, for example, went through several generations of collections development between its founding in 1872 and 2007, beginning as a collection of the first curator's favorite plants, and gradually switching to an emphasis on wild collection in the 1970s. When Michael Dosmann became curator of living collections in 2007, he convened a committee to review the living collections policy and revise it for future needs. The new policy ranked plants by level of documentation and use to the institution, and divided collections into three categories – core, historic, and miscellaneous – with descending levels of priority (Dossmann 2008). The Royal Botanic Garden Edinburgh likewise recently revisited its collections policies to bring coherence to its collections development (Rae 2010).

Identifying Plants: Accession Numbers and Tags

An accession number is be a unique identifier of a single accession, i.e. a plant or group of plants. Different gardens define accessions differently; some consider only single plants accessions, and some will accession a group of plants that enter the garden together under a single number, further distinguishing individuals with other markers such as letters. (Hohn 2008).

The most important considerations are that:

1. Every accession have one, and only one, unique accession number.
2. The accession numbering system be simple to understand and easy to automate.
3. Accession numbers not try to include too much information.
4. When plants die, their accession numbers stay with their records.

Many gardens use a fairly simple numbering scheme that consists of something like the year plus a sequential number indicating which accession an individual plant is for the year. (See, e.g., San Francisco Botanical Garden's (2013) description of its accessioning practices.) So, for example, 2011-0001 would be the first plant accessioned in 2011. The 7345th plant accessioned would be 2011-7345. Gardens that accession groups of plants under one number might use a letter to identify individual plants within an accession group (Hohn 2008). SCBG had historically given each individual plant its own accession number, so we chose to continue with this system.

Each plant receives a physical tag that contains its accession number. This links the plant to its accession record in the garden's database (Hohn 2008). Tags are a perennial problem for gardens. Squirrels chew some of the tags in the SCBG, rendering them illegible (and I have seen the same problem at New York Botanical Garden). Michael Dosmann has complained that visitors to the Arnold Arboretum sometimes steal tags. Without a tag, a plant has in a sense lost its identity; good records and location data can help determine which accession a tagless plant is, but without that data it can be hard to link a tagless plant with an entry in the inventory.

A garden should have a standard procedure for admitting plants into its collection (Hohn 2008). Every plant should enter through the same portal. Allowing staffers to plant items that have not yet been entered into the database is likely to result in those plants never being entered into the inventory at all. Likewise, a standard deaccessioning procedure is wise, so that the garden can track the exit of plants that die or are removed for curatorial reasons.

Data Management

A botanical garden must keep track of the plants in its collection. That sounds simple enough; it should know what is growing where. In practice, that is more easily said than done. Thousands of plants distributed over hundreds of acres have a way of dying, losing labels, creating offspring, being forgotten, and just plain disappearing. In a garden such as SCBG, which has existed for decades, gone through several inventory systems, and never been mapped, old accessions can be hard to locate.

Inventory and Database

Botanical gardens have been tracking their inventories for decades, of course. (In this context, the word "inventory" has two meanings; the noun refers to the list of plants, while the verb form refers to the act of field checking and collating the list.) There are a number of existing database solutions on the market. All of them have advantages and disadvantages, and there is currently no agreement on an industry "standard" software package or data management practices. BGCI has published some guides and case studies on garden information management systems. Some gardens still use index cards to keep track of their accessions. Others use computerized databases of one kind or another ("BGCI" 2013).

Many garden use the software package BG-Base. (As of February 2013, BG-Base listed 202 botanical gardens and other institutions that were using its software.) This software was originally created in 1985 to manage information on biological collections, especially botanical collections. It incorporates collections management with bibliography, taxonomic encyclopedias, distribution data, and people management such as addresses and calendars. It requires users to use coded commands, a skill that necessitates several days of training done on-site by BB-Base representatives, and has specific hardware and network requirements ("BG-BASE" 2013).

Most gardens use other generic software packages, such as Microsoft Access or Filemaker. Consumer database software is widely available. In the case of SCBG, the garden staff wished to be able to access and update plant records in the field. Filemaker's consumer-level database Bento ("Bento" 2013) became available for use on an iPad during my research, and we found that this was a very viable solution. Businesses and organizations of all types have used Bento to organize their data, and the program has an active community of users sharing templates and advice. Bento is easy to use, allows multiple users to share the same library, and is inexpensive. Creating new fields for records is easy.

The garden must decide what data fields it wishes to track on its holdings, both living and dead. Data fields can include the following:

1. Accession number
2. Genus
3. Species
4. Family
5. Cultivar
6. Common name
7. Accession date
8. Status (living/dead, condition)
9. Notes

10. Location
11. Provenance
12. Planting dates
13. Photographs

There are many other data points that gardens could track, such as height, dbh (diameter at breast height), expert verification, and bloom time. Hohn (Hohn 2008) recommends that gardens start simply, keeping track of only necessary information and not attempting to capture every item of data that comes to mind. One advantage of a flexible database such as Bento is that it is easy to add fields to records as they become necessary; the user is not locked into a set of fields that had to be determined at the outset.

The garden's data must to be backed up regularly, and backed up to some location other than the physical garden office. This backup can be a hard disk, a server, or some online service such as Dropbox.

Field Checking

A botanical garden's living collections are living organisms exposed to nature and human visitors. They change constantly, growing, reproducing, and dying. They can lose accession tages. The garden staff must visit them regularly and update their status in the garden's records.

At the Arnold Arboretum in 2011, curators could visit plants in the field with a laptop attached to the garden's database. This made the process of updating records quite efficient; the curator could make changes in the database right in the field, without having to record observations and later transfer them to a computer in the office. In 2013, SCBG found that placing the database on an iPad made it possible to follow a similar procedure of field-checking straight into the database.

Nomenclature

Botanical gardens use scientific nomenclature to identify the plants in their collections, i.e. each plant is identified with a proper binomial and classified by family. Many garden plants are cultivars, which have slightly different nomenclatural conventions. Taxonomy is perennially in flux, which can make it difficult for gardens to keep the correct names on their plants.

BG-Base attempts to handle this problem by integrating taxonomic encyclopedias into the software. There are also many sources of taxonomic information now online. These include the USDA Plants Database ("USDA-PLANTS" 2013), the Integrated Taxonomic Information System ("ITIS" 2013), the International Plant Names Index ("IPNI" 2013), and local floras such as Weakley's *Flora of the Carolinas* (Weakley 2011). Fortunately taxonomic references keep track of former names and synonyms, so it is not crucial for gardens to chase the taxonomy themselves. Outdated names do not invalidate the data.

Data Sharing

Gardens wish to share data with one another, which has led to some efforts to standardize data management. The International Transfer Format for Botanic Garden Plant Records, created by BGCI in 1987, attempts to create a standard list of data fields that gardens should maintain on their accessions ("TDWG: Standards" 2013). The database itself must be able to export garden data in a generic format that can be shared; Bento, for example, can export its data into Microsoft Excel, which is a commonly used format for sharing electronic data. This data can be emailed from one user to another. It can also be posted online on services such as Google's Fusion Tables, allowing a variety of users to access it.

Mapping

Gardens also need to be able to map their collections so that staff and visitors can easily find individual plants. As of 2009, some gardens were using CAD-based systems that could be integrated with database software such as BG-Base. These systems allow the creation of multi-layered electronic drawings and accurate collection maps. Other gardens were using GIS software such as ESRI's ArcGIS. Either type of system could allow for the creation of customizable maps that integrated landscape features and collections. Some of these systems were even available for low cost or free, through ESRI and the APGA, which supported mapping projects (Burke and Morgan 2009, "Esri" 2013).

Mapping technology has proliferated in the past three years. Smartphones, hand-held GPS units, GPS-equipped cameras, and GPS-equipped tablets have appeared on the scene, making it simple to drop pins on maps and show exactly where objects are. These technologies do not require any special training and can interface with the Internet to show precise locations (see, e.g. "Google Maps" 2013). Tablet computers such as the iPad can now access GPS data in the field, allowing garden staff members to geolocate plants on the spot.

METHODOLOGY

My work on SCBG's curation came out of an immediate need. In February 2011, the SCBG applied to become a member of the National American Plant Collections Consortium multi-institutional magnolia conservation group. This is a group of botanical gardens and arboreta that share data and germplasm from their *Magnolia* holdings, reasoning that collaboration among institutions in different geographic areas and with different attributes will make for more efficient conservation of taxa than individual efforts.

The NAPCC application (Appendix D: Magnolias, 166) asked questions about living collections policies, disaster plans, inventory and mapping practices. At that time, SCBG's curation was lacking in several regards. It had no collections policy or standardized curatorial practice. Its computerized database was out-of-date and not accessible online, and used an expensive proprietary software package. The data was in disarray, and there was no way to tell which accession records corresponded to actual plants in the living collection without physically visiting them. There was no consistent mapping scheme, which made it difficult or impossible to locate specific plants in the garden.

In order to join the NAPCC – in order to convince a national group that the SCBG was a scientific botanic garden - the SCBG needed a new inventory database, a new mapping system, and several new policies. It needed these things in time for the NAPCC's site visit, which would occur in the next several months. And nothing could cost much or be difficult to use.

Living Collections Policy

To create the SCBG's Living Collections Policy (SCBG Living Collections Policy, 151), I borrowed freely from the structure of the Arnold Arboretum Living Collections Policy.

SCBG's Living Collections Policy takes into consideration the SCBG's history and existing collections as well as Dr. McMillan's new Natural Heritage Garden, which showcases native South Carolina plants in as close to a natural habitat as is possible to achieve in a cultivated setting. It emphasizes the SCBG's conservation collections, essential for entering the NAPCC as a member of the multi-institutional magnolia conservation group.

The Living Collections Policy is intended to be concise, philosophical and vague enough to allow for interpretation. It is a policy, not a manual, and is meant to give the director, curator, and collections committee the flexibility to determine what the garden should or should not grow. A garden with many donors and other stakeholders may find itself captive to their wishes, and end up growing plants that do not mesh with its mission because donors have given money to grow specific plants. A policy such as this one could give a director justification to decline donations that dictate collections and to refuse to grow particular taxa that do not fit with the garden's overall vision. If a garden needs more specifics about the details of what to collect, it could create a separate collections development plan and/or curatorial manual that describes the details of acquisitions, plant maintenance procedures, database policies, nomenclature, etc.

Identifying Plants: Accession Numbers and Tags

SCBG needed a consistent procedure for assigning accession numbers to new objects in the collections. The staff and I decided that the simplest solution for the SCBG would be an 8-digit year-number system, e.g. "2011-0022" would be the 22nd accession of year 2011. It would be easily automated and would never need to change down the road. Every number would be unique, and every number would contain the valuable information of year of accession. Woody plants would each receive single accession numbers. Plants that grow in clumps, such as many perennials, could receive one number per clump.

We discussed the possibility of adding a letter, such as N or W, to identify the plant's origin, i.e., either wild or nursery. We concluded that this was too much information. It would be an unnecessary complication, and could lead to problems later if we decide that we either don't need that letter or want to add another one. Likewise, we concluded that it was easiest to keep accession numbers as just numbers, without adding letters to distinguish individuals within group accessions.

In the past, some plants entered SCBG's living collections without having first been recorded in the database. The result was occasional plants growing in the garden with no corresponding entry in the database. Relying on staff members' memories to reconstruct the history of plants was not a viable solution for data management.

The staff and I agreed that the garden needed some sort of policy describing procedures for adding plants to the collection and removing plants that no longer fit collections goals. Accordingly, I wrote and Accessioning Policy (Appendix B: SCBG Accession Procedure, 161) to standardize the process by which plants enter and leave the garden's collection. Under the new policy, all new plants will enter through one site, the nursery mat, and be accessioned at that point; they do not enter the garden without an accession number and tag affixed.

Data Management

The garden staff wanted a quick, easy, and efficient way to keep track of the garden's holdings. They wanted to be able to update plant records in the field and to add GPS coordinates and photos to records.

Putting SCBG's inventory in order was a challenge. As of March 2011, the SCBG had 10,538 accession numbers in its database. This number was not a reliable indicator of the garden's actual holdings. The database was full of erroneous entries, and the only way to determine exactly how many plants the garden actually held was to visit each plant individually and update its records.

The inventory software program was another problem. In the 2000s, the SCBG garden manager transferred the garden's inventory into a program called ArborVue (http://www.arborvue.com/), designed for the forestry industry and produced and sold by the Laurus Group. Based on what I saw of it and the manager's own comments, ArborVue was difficult to use, expensive, inconveniently held data hostage at the end of the year until the licensing fee was paid, and produced a map that was based on screen pixel locations, not GPS coordinates. When the manager first installed this program and transferred the existing database to it (garden staff reported anecdotally that the data had formerly been in Microsoft Access), ArborVue excised initial zeros from old accession numbers, forcing the manager to assign new accession numbers to many plants; as a result, many plants in the collection had multiple accession numbers. In addition, technical support from the Laurus Group was extremely slow. The garden staff agreed it was time for a change of software.

A great deal of information apparently resided solely in the memories of individual humans. Previous staffers allegedly did not always record planting locations or the deaths of plants. Data stored in human memory has a way of disappearing completely.

SCBG has limited financial resources, a small staff with no full-time plant registrar or curator, and very little computer expertise. My goals here were to first assess the garden's status and then create a way of organizing the data that was simultaneously efficient, easy, and cheap. The garden staff worked together on this project, because the end result had to be something they could use.

I was greatly helped in this work by a visit to the Arnold Arboretum in May 2011 to learn about its curatorial practices. I experimented with the botanical garden database program BG-Base, participated in field checks and mapping, visited the herbarium, and discussed various curatorial challenges with the arboretum's staff. (Plant tags are a perennial problem; squirrels eat SCBG's, and visitors steal the Arnold's.) Seeing a major botanical garden's practices firsthand was invaluable in my work on the SCBG's own curation, and it also reassured me that even the best-run institutions encounter difficulties in keeping track of their collections.

Assessing the situation

I spent February 2011 exploring SCBG's inventory and collections. I focused on the magnolias, in preparation for the NAPCC's site visit.

My most immediate objective was to create an accurate list of *Magnolia* accessions and locations. Excluding the 125 listed *Magnolia grandiflora*, a common cultivated plant of no particular conservation interest, there were 197 members of the genera *Magnolia*, *Michelia*, and *Manglieta* listed in the garden's database. This list included a number of dead plants, so the true number of *Magnolia* in the garden was something less than 197, though how much less I had no idea. (See Appendix D: Magnolias, p. 166, for the list of magnolias SCBG initially sent to the NAPCC in 2010, before any cleanup began.)

I found many discrepancies between the inventory data and the actual plants on the ground. These problems fell into numerous categories:

1. Registration errors
    a. Plants with more than one accession number; e.g., a *Magnolia salicifolia* identified as both 10461 (new number) and 67114 (and before that 067114).
    b. Accession numbers attached to more than one plant, e.g. 940198 identified a *Magnolia figo* and a *Salix alba* 'Snake'.
    c. Accession numbers with no apparent plants. I could not find several magnolias listed in the inventory, and had no good way of determining

whether or not these things were dead or labeled with different accession numbers. Examples: 7628, 7366, 7369, 740027.

d. Plants with one name in the database and a different one on the tag: e.g., 7620 was labeled *Magnolia cavaleirei*, but was identified as *Magnolia maudiae* in (one version of the) database.

e. There was no accession date recorded for any plant.

2. Lack of Inventory Control

   a. Plants with no accession number. For example, there was a *Magnolia officinalis* in Block 11 of the Shoeneke Arboretum with no accession number and no entry in the database. (Note: this is not the same as plants with missing accession tags.)

   b. Plants with no accession tags.

   c. Dead plants not clearly marked in the database as dead. Some plants were marked "Lost" in the condition field. Others had no data at all in this field.

3. Locations were poorly identified, making it very difficult to locate plants.

   a. Problems of nomenclature (i.e., "nomenclutter")

   b. Plants with incorrect species names, e.g. 10249: labeled *Michelia figo* spp. *crassipesq* in ArborVue database.

   c. Some plants were in the database under two different scientific names with two different accession numbers.

One major problem was the plants with multiple accession numbers. The database contained four accessioned *Magnolia salicifolia*. At least two of those numbers referred to the same plant. One of them referred to a dead plant. Another one had allegedly been planted near the Hanover House, but I never found it. I failed to locate a number of listed *Magnolia ernestii*, and I had no way of knowing if that was because they are dead, because they were in fact labeled with other numbers, or if I was just not seeing them.

Possible solutions

We needed a quick solution to the database problem. We needed to have our data looking respectable by the time of the NAPCC site visit, which gave us just a few months. There were several options for a database:

1. Microsoft Excel. We exported the inventory from ArborVue into Excel, which is currently the standard program used to exporting CSV data, sharing it, and importing it into new databases. But Excel is not a database and not ideal for managing large collections.
2. Microsoft Access. It is a database so is designed for this type of job. Missouri Botanical Garden uses it. It was already installed on the SCBG computers. This was and still is a possibility.
3. Some other general-purpose database such as FileMaker or its consumer version Bento ("Bento" 2013). Bento became available for the ipad during the time I was working on this project.

4. BG-Base. This is a specialized database used by many institutions in the botanical garden community, including some of the most exalted ("BG-BASE" 2013).
5. Use Clemson's own computer experts at CCIT to build a database. The garden could take advantages of technical services already provided by the university.

We considered BG-Base, largely because so many institutions use it and it has some status as an industry "standard." I concluded, however, that it was inappropriate for SCBG. Aside from the fact that it is expensive and proprietary, based on personal observation and the online user discussion boards, it appears to be difficult to use. Implementing the system requires a garden to pay for BG-Base representatives to travel to the site to install the software and spend at least two days training the staff. Using the system requires staff members to become fairly proficient at computer coding. The technical support discussion boards for BG-Base contain rather daunting question-and-answer exchanges about specific coded commands (this discussion forum is open only to registered users, but is available on BG-Base's website). SCBG's staff has good consumer-level computer skills, but they are not programmers and they do not have the time or interest in learning programming in order to access and use their database. By 2011, and certainly by 2013, there were technologies available that were much easier to use and required little or no training time to implement.

Clemson's custom database – only a temporary solution

In the spring of 2011, we ended up choosing the last of these options, creating our own database housed on Clemson's servers. This solution met our requirements of ease of use, low cost, and rapidity of implementation. Harold Tillett, a web developer for Clemson PSA (Public Service Activities), agreed to take on the project. He programmed a database that incorporated all the fields we had requested, including a dead plant field (so that the staff could separate out records of plants known to be dead). This database was up and running by early August of 2011, and the staff were using it to keep track of plant records.

The Clemson custom database had several advantages over the old system. It cost the garden nothing except human time. It was easier to work in than Excel, which is not ideal for manipulating large numbers of complex records. It stored the data off-site and was backed up every night. Smaller searches were easily exported into Excel for other uses. Ms. Kathy Bridges, the landscape manager, did most of the work updating plant data in 2011-2012. She found the database adequate, and had already used it to clean up portions of old data and to map regions and collections. She worked well with Mr. Tillett to request changes in the program and to update data.

On the other hand, the system was lacking in many regards. It was slow because it had to access off-site files. It was impossible for a registered user to get a dump of the entire dataset; Mr. Tillett would provide the data if requested, but this locked up the data in his hands, which was not at all what we wanted. Adding photographs was not easy, and they seem not adequately attached to records. Worst of all, the database was incompatible with standard web-browsing software (it worked only with Internet Explorer) and did not work at all on any mobile device (again, because it did not support standard internet technologies). That meant it would not work for in-the-field updates on mobile devices.

This lack of mobile accessibility made this database unacceptable for a long-term solution. The staff agreed that they needed a system that would allow them to update the database in the field, so we looked for another system.

Bento and an iPad: One-stop field checking and mapping

In January 2013, Ms. Bridges acquired an iPad. This device and similar tablet computers could revolutionize garden curation, making it easy to update records in the field, while photographing and mapping accessions directly into the garden's database.

Ms. Bridges and I got a complete and current set of SCBG's database from Mr. Tillett and used it to create a new library in the database program Bento ("Bento" 2013), which we installed on Ms. Bridges' computer.

This allows Ms. Bridges to do exactly what she had long wished to do: update records in the field, next to the plants in question. The iPad has a camera, allowing the user to take photographs and insert them directly into records. It also comes equipped with GPS, allowing mapping in the field. When Ms. Bridges returns to the garden office, she can sync the new data from the iPad directly into her computer with one click. The entire process is vastly more efficient than all the other solutions to curatorial problems I described in this chapter.

Why did I not implement this solution right at the beginning of this project? The technology did not exist at the time. The burst of consumer-level technologies that have appeared in the past few years has suddenly made it very easy for an institution with limited resources (and little technological expertise) to organize its data quickly, efficiently, and with a high degree of accuracy. Bento has an active online user community with ample assistance for users, so the garden staff can trouble-shoot problems themselves.

This solution, as always, is not perfect. I have not figured out how to automate the creation new accession numbers without changing all the old ones; automating these numbers is desirable as a failsafe against duplication, but I do not know how to do that in a situation where that field has already been filled in existing records. Sharing of the library is limited to five users on the same network. Bento is a Mac-only application, so it will not work on Windows computers.

Technology has improved rapidly in the past few years, and is likely to continue to do so. Maintaining the garden's data will be an ongoing project. The most important thing is that the data itself be clean. Technologies will come and go, but if the data are good, it will retain its value.

Mapping

A botanical garden's curators should know where their plants are. They should be able to locate any accession, either on a map or on the ground. In 2011, SCBG could not reliably do this.

As of early 2011, the garden's inventory identified plant locations with a broad brush – "Specialty Arboretum," or "Hortitherapy Garden." Some plants were located in places that no longer went by a particular name, such as "Fox Den." There seemed to be no single map that combined all the garden's locations on one page. (See C.1: Map, South Carolina Botanical Garden, Annotated, p.166, for a garden map with locations labeled by hand by garden staff.) Some plants were described only as living in the "Shoenike Arboretum," which encompassed over 100 acres. The Shoenike Arboretum was divided into a series of blocks, a system that worked well when block location data were included in plant records, but it only applied to the arboretum area, not to the garden as a whole (C.2: MAp, Shoenike Arboretum, p.166). No plant had GPS data recorded.

The garden staff needed a simple method to map the accessions. GPS coordinates were the logical format. ArborVue and some other programs that were produced before the advent of widespread GPS technology to map objects onto idiosyncratic grids. This wasgood for producing printed paper maps but difficult to integrate with electronic mapping. Now that GPS technology has been built into a wide variety of consumer electronics, including phones and cameras, and mapping has become easy with Google Earth and other online options, it seemed sensible to use GPS data to map plants.

Mapping with a camera

In early 2011, several point-and-shoot cameras equipped with GPS entered the market. I acquired a Sony Cyber-Shot point-and-shoot camera small enough to fit in my pocket and carried it with me while I walked around the garden looking for magnolias. When I found one on my list (or not on my list, as the case may be), I photographed the accession tag. The camera recorded the location in the photograph's metadata.

I developed the following method for mapping plants in the garden:

1. Photograph accession tag.
2. Import photograph into iPhoto.
3. Copy GPS data from photo using a script written for this purpose.
4. Paste GPS coordinates into database.

Ms. Bridges used this technique with another point-and-shoot camera throughout 2012, with good success. It is fairly quick and easy. Placing the accession number in the photograph makes it easy to verify which record goes with which plant. The photographs themselves are a backup source of location data; locations remain embedded in the images. Ms. Bridges also successfully used student workers to map plants with this method, giving them the camera and instructions to photograph accession tags.

This method has several disadvantages. I found my Sony Cyber-Shot camera to be reasonably accurate but not perfect. For the most part, it gave coordinates of objects that were at least within sight of the accession in question. Occasionally it produced wildly inaccurate results; it was sometimes slow to find a new signal and would use its last location until it found one, which caused it to geolocate Clemson trees in places such as Greenville, another city entirely. This meant that anyone entering GPS data into the database needed to double check Google Earth images of locations before using the data, which is a good idea anyway and was a quick, one-click process.

Disadvantages aside, the GPS-equipped camera allowed the garden to create real-world digital maps of its collections, and at little expense. For 2011-2012 at least, this system worked well. The results can and will be refined over time.

Mapping directly into the database

In 2013, the garden moved its database to the program Bento, which allows users to perform field checks with an iPad. Ms. Bridges can now add location data directly into plant records in the field, a much more efficient process than the one with the camera.

RESULTS

In September 2011 Frank Telewski came to Clemson to perform the site visit for the NAPCC application. Because of the work the staff and I had done, we could show him good data on our magnolias, including a map of individual accessions (Appendix D: Magnolias, p.166). I carried my iPad in the field to illustrate how in the future it should be possible to do field checks on site. Dr. Telewski was satisfied with our application, and the SCBG was admitted to the NAPCC.

By 2013, SCBG's staff could do what it had requested two years earlier: visit plants in the collection with a tablet computer and update records on the spot. They were in the process of performing an inventory of the complete collection; this process obviously would take some months, but was greatly facilitated by efficient processes.

Because the data and policies are in place, SCBG found it much easier to complete the application for another conservation organization, the Center for Plant Conservation, in 2013. The creation of new collections will go more smoothly and produce better data because the staff has the technology and the protocols to track it well.

DISCUSSION

SCBG is not alone in struggling with its inventory. Many scholars have observed that gardens often do not have good records of their holdings, or have not stored their data in a way that is easily shared (Pautasso and Parmentier 2007). Andrew Bunting, chair of the NAPCC's magnolia group, in a personal communication in 2011 told me that it was not unusual for first-time applicants to the NAPCC to need to work on their curatorial practices, including mapping, inventory, and policies.

Improving records is crucial to making collections accessible to researchers. Gardens that wish to be effective conservators of plant biodiversity should be able to quantify their efforts in a measurable way (MS Dosmann 2006). Documentation is the basis of many types of research, and gardens can collect many kinds of data. Dosmann suggests identifying all collections material according to genotypic biodiversity, environment and source history, and phenotypic diversity. Genotypic diversity data includes information in taxonomy and populations. Environment and source history includes an accession's provenance, its location in the garden, georeferences, descriptions of habitat and related species, and all information about the collection act. Georeferencing plants in the garden itself can be very useful for monitoring of habitats, soils, climate, and maintenance. Some gardens use dataloggers to track environmental data over time. Phenotypic data includes observations on plant performance, phenological data, digital images of plants, and other measurements that can be gathered on a regular basis and used to identify patterns over time. All information is more useful if it is assembled in a form that other institutions can share and use. A number of institutions have been collaborating on databases to improve sharing of information on biological collections (MS Dosmann 2006).

Kayri Havens and Pati Vitt at the Institute for Plant Conservation at the Chicago Botanic Garden have created a set of performance indicators that gardens can use to assess their work. Assessment categories include protection and management, including native habitats, species in ex situ conservation collections, and species in formal reintroduction programs; law and policy, including advocacy for conservation, certification of facilities by federal authorities for endangered and threatened species work, and institutional missions linked directly to issues such as sustainability; education and awareness, including outreach and teaching displays; changing incentives, such as contributions to local sustainable development and using market pressure to promote sustainable practices; and institutional investment in conservation. The authors note that although many gardens are active in taxonomic research, many fewer are leaders in applied conservation research. They emphasize the importance of improving professional capacity by cultivating links with other gardens and working more to support in situ conservation with ex situ conservation programs (Havens et al. 2006).

Georeferencing and GIS data are increasingly important in conservation efforts. For example, the Balkan Botanic Garden of Kroussia, Greece, has used GIS data to define the ecological profiles of the in situ living conditions of endangered species. This data links ex situ and in situ populations and facilitates the determination of propagation methods (Krigas et al. 2010).

Collections Development

The SCBG's new collections development will follow the new Living Collections Policy, which sets priorities for different types of collections. All new accessions will meet specific collections goals, especially the goals of conserving endangered species and nurturing South Carolina native plants. The garden will maintain detailed records on the provenance of all new accessions.

Dr. McMillan is in the process of designing a new garden representing a cross-section of South Carolina habitats. It will include a coastal forest and longleaf pine savannah, a canebrake, a dry Sandhills habitat, a Piedmont prairie, a Piedmont forest, a Carolina bay, and a granite outcropping. All of these habitats will feature native plants, illustrating natural communities as they exist. Many of the plants we use will be endangered species, many collected from wild habitats.

Populating this garden will require the SCBG to collect a vast number of plants from wild habitats. This will require us to consider various aspects of collections, including ecology and landscape design, botany, horticulture, seed storage and propagation, as well as conservation laws. It gives us an opportunity to involve local volunteers and Clemson students as well; both of these groups can help collect and plant the new collection, and both can benefit from the educational experience.

Developing this collection will also require the SCBG to cultivate relationships with plant specialists and breeders. We are very fortunate to have several plant experts in the local area, including world-renowned magnolia authority Dick Figlar and native fern expert Tom Goforth. The garden has already begun collaborating with them to verify plants already in our collections and to add accessions from the taxa that they collect and breed.

CONCLUSION – FUTURE DIRECTIONS

The botanic garden community is increasingly involved in multi-institutional collaborations. Different institutions can grow different plants due to climates and facilities; if gardens are to make a serious contribution to ex situ plant conservation, they will have to work together to ensure that all relevant plant taxa are being grown somewhere. Clemson can grow plants that don't thrive in other areas, and it has a large amount of space, which could make it a valuable participant to national and regional efforts. Some things we could do include:

1. Consider joining the Center for Plant Conservation (CPC) and Botanic Gardens Conservation International (BGCI).
2. Information sharing: Once our inventory is cleaned up, share our holdings information with the rest of the world through a BGCI Plant Search upload.
3. Place database online. Garden users would benefit from being able to search for individual plants.
4. Make connections with local plant experts. Dick Figlar, magnolia expert, was instrumental in our being accepted into the NAPCC. Tom Goforth is a local fern expert who has been a great supporter of the garden.
5. Match up historical records and herbarium specimens with current inventory.

In the future, the SCBG could consider adding to its curatorial materials a Collections Development Plan, a more detailed document explaining exactly which taxa the garden wants to collect and how it goes about performing building a collection. It could also add a curatorial manual/landscape management plan, which would be a guide for curators, explaining how the garden's curation and landscape management operate.

The SCBG might also add a curator to its staff, a professional whose job would be to consolidate supervision and operations, along with oversight of records, planning, etc.

This would most certainly lead to further gains in efficiency and thus better overall collections development and maintenance.

CHAPTER 3: STUDENT INVOLVEMENT

A botanical garden interested in increasing its relevance and maintaining its financial support must attract visitors and volunteers. It must also show that it is conducting scientific and educational endeavors that go beyond merely maintaining a lovely park with some exotic plants. Getting visitors involved in the garden's work is a good way to increase their enthusiasm for conservation and science.

A garden based at a university has a set of stakeholders unique to an academic environment. Groups of people with legitimate interests in university gardens include students and faculty who engage in education and research, the local horticulture industry, and members of the local community who visit the garden for recreation and education. Gardens can cultivate all of these relationships with an eye to future financial support. Engaging students who will become alumni is particularly valuable (Scoggins 2010). Dosmann (2006) has suggested that gardens need to make research a fundamental component of their work, and that research will both improve collections management and keep collections relevant. Citizen science, especially citizen science involving students, is an area with many opportunities to collaborate with the public (Donaldson 2009a).

This chapter describes one effort to involve undergraduate students in the work of the SCBG. During the academic year 2011-2012 Dr. Jeff Adelberg and I conducted a Creative Inquiry, Hort. 408, Plant Collection for the Botanical Garden. This independent study class was intended to introduce students to scientific plant collection while serving the practical purpose of acquiring wild plant material of documented provenance for the new Natural Heritage Garden and exploring some ways to use the garden for teaching and research. It was also intended to develop methods that the SCBG could use in future collections development, collecting wild plants with the provenance information and herbarium vouchers that are essential for scientific or conservation collections. During the course of a year, the undergraduate students planned collecting trips, collected plants in the field, recorded GPS locations and soil pH, transported the plants to the garden and potted them up to await planting, made herbarium vouchers. They also participated in a national Citizen Science project, Project Budburst, observing the phenology of plants in the garden and submitting their findings to the online Project Budburst database. The experience gave them insights into the missions of botanical gardens and the importance of data collection as well as practical experience with field botany and plant propagation.

The results of this project were encouraging. The students enjoyed the work and claim to have learned from it. They got to see the process of garden collection from wild plants in the field to incorporation in the living collection. The garden curators used the opportunity to test new curatorial practices and the new database. The garden received a number of plants of documented wild provenance for a specific collection. Experiences such as this one could be a valuable addition to the university's teaching catalog, giving students real-life skills and creating lifelong botanical garden enthusiasts.

INTRODUCTION

Creative Inquiries at Clemson are meant to give undergraduates hands-on experience doing real, independent work that is not constrained by classroom scheduling.

Dr. Adelberg and I described Hort. 408, Plant Collection for the Botanical Garden, as follows:

Course Description: This Creative Inquiry will collect plant materials for the new South Carolina native plant collection in the SC Botanical Garden. Students will travel to sites throughout South Carolina to collect plants, fruits, seeds, and other propagation materials and then propagate them in the greenhouse. Along the way they will collect detailed information on the locations of the parent plants, voucher specimens for the Clemson herbarium, and research the particular requirements for propagating different types of plants. They will also learn about plant conservation and rare and endangered species. The resulting plants will become part of the SC Botanical Garden's collection.

Course Learning Outcomes: 1. An understanding of plant taxonomy and the ecology of different SC ecosystems 2. Practice in plant collection, propagation, and synthesis of environmental requirements 3. Practice in GPS, mapping, photography, and record-keeping 4. Some exposure to conservation laws and other factors limiting plant collection

Dr. Adelberg and I advertised the class to students in his Plant Propagation class during the preceding semester; though there were no prerequisites for this independent learning experience, it made sense to target students who already knew something about handling plant materials.

Before the class met, Dr. Adelberg and Dr. McMillan and I discussed the garden's collection needs and possible sites for the students to collect plants. Dr. McMillan gave me a list of several hundred Cove Forest species that he wanted for the Cove Forest section of the Natural Heritage Garden and suggested some potential collection locations. He also suggested that we might spend a weekend on the coast to collect coastal plants.

METHODOLOGY

Four students attended this class: Emily Harrington, Lauren Duncan, Jessie Brown, and Tobbi Stewart.

Before our first class meeting, I assigned the students a few short readings. These included:

1. Information on botanical gardens from BGCI's website;
2. The SCBG Living Collections Policy; and
3. Rae's "Fit for Purpose: The Importance of Quality Standards in the Cultivation and Use of Live Plant Collections for Conservation" (Rae 2010), which describes the goals of modern living collections and the importance of provenance.

The purpose of these readings was to give the students some notion of the scientific basis of living collections and the importance of building a collection of wild material with provenance attached to it.

At the first meeting, the four students divided themselves into two groups based on what we believed at the time would be our collection regions: Cove Forest and Coastal Plain. I gave all the students a shortened list of Dr. McMillan's cove forest plant wish list that included 28 common and easily recognized plants from the Clemson area and a number of common local ferns. The two students initially handling cove forest plants divided the list into woody and herbaceous materials, and spent the next few weeks researching those plants and their propagation.

We considered several possibilities for cove forest collection sites, including Wadakoe Mountain and the Eastatoe Valley, Aul Natural Area (especially for wild ginseng, *Panax quinquefolia*), and the Clemson Forest. We also considered paying a visit to Dick Figlar's magnolia arboretum in Six Mile to collect seeds from his rare Asian magnolias to propagate in the greenhouse.

Ultimately, the easiest and most practical site to visit was the property owned by several members of the Bowie family on Wadakoe Mountain. This site had several advantages: it was private property, so we did not need a permit, Dr. McMillan knows the Bowies, who generously granted us permission to collect on their land, and it contained a huge variety of desired taxa. In addition, Alex Bowie was an undergraduate at Clemson, and he agreed to lead our first group to his family's property.

We were constrained in our scheduling by the seasons. Most deciduous plants in the upstate have disappeared by late October or early November, and the days get too short to do outdoor work in the afternoons, so we had to collect most of those plants by the end of October.

October 7, 2011 Collection Trip

We made our first collection trip on Friday, October 7. Alex Bowie met us at the greenhouse and we drove out to Wadakoe Mountain. Tom Goforth, a local fern expert and geologist, met us there at the collection site. We brought the following equipment:

1. shovels and trowels
2. Many plastic grocery bags
3. Zip-lock baggies
4. Pencils and sharpies
5. Knife
6. Two GPS units
7. Clipboards and paper
8. pH meter with bottle of water and beaker for testing soil
9. Plant press and temp press with lots of newspaper checked out from herbarium curator Dixie Damrel

The two students had prepared notes on various plant species, and one of them had made note cards with photographs of her plants to help her identify them in the field.

We stayed at the foot of the mountain in a forest at the boundary of a floodplain agricultural field, collecting ferns and other herbaceous and woody plants that grew close to the bottom. We had expected to collect a number of seeds, but instead ended up collecting many whole plants. We dug up the roots and placed them in the plastic grocery bags, which we labeled with sharpies. The students recorded the GPS points of the location from which each plant was collected. They also gathered soil specimens and used these to test the pH of soil at collection sites. At the end of the evening, we took small specimens from each collected plant and put them in the temporary plant press. I took these specimens home that night and put them in the large plant press, which I delivered to the herbarium the next week. Dr. Adelberg drove the students and crates of plants back to Clemson, dipping the crates in a creek as they left the area to water all the plants at once. Conditions were very dry at the time, and the soil around all roots was quite dry.

Before we left the site, Dr. Adelberg and Mr. Goforth and I agreed that we had not nearly exhausted the potential of the area, and that instead of going to a completely different location near the coast for our next collection trip, we should return and venture further up the mountain.

The next Monday, the two students took the collected plants to the South Carolina Botanical Garden to pot them up. Ryan Merck, the botanical garden's nursery manager, helped them and provided some feedback on our collections. He agreed to join us on our next collection trip so that he could select plants that he knew the garden would need.

October 21, 2011 Collection Trip

On October 21, Dr. Adelberg, Ryan Merck, and I took our other two undergraduates back to Wadakoe, where Tom Goforth met us again. This time we walked up into the wooded dissected slopes of the mountain and collected plants at various elevations. The students recorded the GPS of the sites and took soils samples again; it was quite interesting to see the soil pH become more acidic as we ascended from the lower narrow forest on the floodplain edge to an acidic ridge-top, a change that the students themselves remarked on as the composition of the vegetation changed from species-rich deciduous forest to evergreens (pines, rhododendrons, and blueberries) in the lower pH environment. Although the substrate of the floodplain and the lower slopes of Wadakoe Mountain is felsic Henderson Gneiss that yields very acidic soils, it was assumed that the higher pH of the floodplain was caused by agricultural liming and/or hydrologic deposition of basic cations from upslope mafic rocks. We made it up and over the ridge and almost to the top of the next ridge where we reached the Eastatoe Fault, the boundary between the Henderson Gneiss and the mafic Poor Mountain Formation that underlies Wadakoe Mountain from the fault to the top. We had noticed a decrease in acidophile flora a few hundred feet before the fault, and around the fault, soil pH was measured at 7.0. We were then forced to turn back because of impending darkness.

Carrying plants and gear was more difficult this time because we had to bring everything with us; on our previous trip we could leave bags of plants at the edge of the woods and carry them straight to the truck. This time we had to carry crates with us, quite difficult on this rugged terrain. We followed the same post-collection procedure, driving the plants to Clemson, potting them up the following week, and bringing pressed specimens to the herbarium.

Kathy Bridges, the garden manager, took our lists of collected plants and made labels for them. She entered the new plants into the garden's database with provenance and collection information included in the entries. The plants are in the garden's database at accession numbers 2011-0239 to 2011-0257 and 2011-0279 to 2011-0298. (See p.80 for the list of collections.)

The students met at the herbarium later that semester and prepared herbarium vouchers for all the plants we had collected.

We met one last time in December to look at the herbarium specimens and discuss our work. The students were all enthusiastic about the experience.

Spring 2012 Collection Trip and Project BudBurst

We continued the Creative Inquiry during the spring semester with only two students. By this point Dr. McMillan was actively planting the Cove Forest section of the Natural Heritage Garden (for which he used materials this class had collected in the fall, along with many plants from other sources) and had much more specific collection needs. In addition, spring collection had to wait until plants broke their dormancy, which meant we could not collect until the second half of the semester. (Warm spring weather happened to arrive unusually early in 2012, but we had too many people and too many personal calendars to be able to respond quickly to this unexpected warm weather.)

Dr. McMillan requested that the Creative Inquiry students collect yellowroot (*Xanthorhiza*) and dog hobble (*Leucothoe*) to plant along the creek bed in the garden. To give the students more scholarly work, I had them research the medicinal uses of yellowroot and the ecological significance of canebrakes, with the possibility of incorporating this research into the garden's informational materials. I also had them file Project Budburst reports on various taxa in the garden (3.5 Table - Project BudBurst Data, p.81); this early spring was an opportunity for them to participate in national-level citizen science and to use the SCBG for scientific data-collection of their own.

On March 9, the two undergraduates met me and SCBG landscape manager Kathy Bridges at the garden office. We drove from there to Ms. Bridge's house in Eskew Springs, near Oconee State Park. Ms. Bridge's husband drove us out to a site on the property that contained a great quantity of yellowroot and dog hobble, which was simple to dig up. The students filled several 20-gallon plastic garbage bags with plants, taking GPS readings for the database and potting up the plants for transport back to campus. The following week they planted the material directly in the garden, next to the creek where Dr. McMillan wanted it. The students once again mounted vouchers for the herbarium.

The students did their reports for Project BudBurst entirely on their own. Project Budburst ("Project BudBurst" 2013) is a national citizen science project gathering data on plant phenology. This project allows citizens to file reports on the timing of plant activity in their areas. For each plant, a participant observes it on a particular day and records whether it is leafed out or whether the leaves are changing color or dropping, whether it is flowering and if so whether it is in the early, middle, or late stages of flowering, and whether it is in fruit. The work requires observers to identify plants and to use their judgment about what phenological stages they are in.

The students in this class filed Single Reports, one-time reports on individual plants. (Project Budburst also collects data from regular observations of the same plants, which could be a good project for a botany class that can visit the same plants multiple times over a season.) The Single Report project is very good for interested amateurs because it does not demand a long-term commitment to watching particular plants and it requires the most basic of scientific observations. The students chose which plants to observe, arranging a time to visit the garden, and submitting their reports. On their own initiative, they looked up the list of plants that Project Budburst recommends for monitoring in South Carolina and found examples of those growing in the botanical garden. It turned out that *Xanthorhiza* had not yet been entered into the Project Budburst database, so they created a new entry for that.

We had asked them to take GPS coordinates of the plants they visited for Project Budburst as part of the garden's effort to map its collections, and they did so. Unfortunately, they did not record accession numbers with these data, so it was impossible to determine which specimens they had mapped.

At the end of the semester we met out at the garden. The students gave reports on their topics, and shared their Project Budburst results. We walked down into the new Cove Forest display, which at that point was quite thoroughly planted with native species. We found a number of plants that we had collected at Wadakoe, which Dr. McMillan had incorporated into his design. I showed the students the database entries for their plants, including the provenance information that went with them.

RESULTS

This creative inquiry produced several types of results. It added actual wild-collected plants of documented provenance to the South Carolina Botanical Garden's living collections along with corresponding entries in the garden's database and the herbarium vouchers. The students themselves learned a great deal and had experiences that will affect how they think of the natural world and botanical gardens in the future.

3.1 Table - Plants collected, 7 October 2011

Johnny and Larry Bowie's property, behind 807 Cleo Chapman Hwy, Sunset SC, 29685

Eastatoe Valley/Wadakoe Mountain . (The pH for all of these collections was 5.4.)

Magnolia fraseri	Fraser magnolia	34.9869, -82.83695
Actaea racemosa	black cohosh	34.9869, -82.83695
Aeculus pavia	buckeye (seeds)	34.9869, -82.83695
Mitchella repens	partridge berry	34.986167, -82.838417
Lindera benzoin	spicebush	34.986167, -82.838417
Polygonatum	Solomon's Seal (seeds)	34.9875, -82.836067
Hamamelis virginiana	Witchhazel	34.9875, -82.836067
Juglans cinera	butternut (seeds)	34.9875, -82.836067
Asimina triloba	pawpaw (seeds)	34.9875, -82.836067
Calycanthus floridus	sweetshrub	34.986683, -82.837267
Eurybia divaricate	white wood aster	34.9863, -82.828633
Tiarella cordifolia	heart-leafed foamflower	34.886217, -82.838417
Sanguinaria Canadensis	bloodroot	34.986733, -82.837222
Helianthus glaucophylla	white-leafed sunflower	34.986733, -82.837222
Adiantum pedatum	Maidenhair fern	34.98705, -82.837133
Athyrium asplenioides	Southern Lady fern	34.98705, -82.837133
Deparia acrostichoides	Silvery Glad fern	34.98705, -82.837133
Botrychium biternatum	southern grapefern	34.98705, -82.837133
Euonymus Americana	hearts-a-bustin'	34.9864, -82.83805
Onoclea sensibilis	sensitive fern	34.986867, -82.8375
Polystichum acrostichoides	Christmas fern	34.987033, -82.836817
Thelypteris novoboracensis	New York fern	34.986667, -82.837267
Phegopteris hexagonoptera	Broad Beech fern	34.9869, -82.837167

3.2 Table, Plants collected October 21, 2011

David and Nancy Bowie Martin's property, behind 807 Cleo Chapman Hwy, Sunset SC, 29685. Eastatoe Valley/Wadakoe Mountain.

Pleopeltis polypodioides	34.9873	-82.832567	pH 5.2	
Goodyera pubsecens	34.987194	-82.8325	pH 5.2	
Euonymus obovata	34.987194	-82.8325	pH 5.2	
A Nettle?	34.986917	-82.8325	pH 5.2	
An Iris	34.986917	-82.8325	pH 5.2	
Osmunda cinnamomea	34.986917	-82.8325	pH 5.2	
Decumaria barbara	34.986917	-82.8325	pH 5.2	
Prenanthes altissima	34.986633	-82.831667	pH 5.2	
Athyrium alsplenioides	34.986683	-82.832583	pH 5.4	
Magnolia fraseri	34.98645	-82.832467	pH 5.4	
Kalmia latifolia	34.98645	-82.832467	pH 5.4	
Vaccinium pallidum	34.9865	-82.833083	pH 4.5	
Sassafras albidum	34.986133	-82.832317	pH 4.5	
Symplocos tinctoria	34.98615	-82.832333	pH 4.5	
Lobelia siphilitica	34.985111	-82.833194	pH 5.5	

Smilicina racemosa	34.985111	-82.833194	pH 5.5	
Carex	34.984683	-82.8329	pH 5.5	
Calycanthus floridus	34.984683	-82.8329	pH 5.5	
Halesia tetraptera	34.984317	-82.833133	pH 7.2	
Eupatorium perfoliatum?	*34.98425*	-82.833183	pH 7.2	
Prosartes languinosa?	34.984267	-82.833183	pH 7.2	
Viola	34.984317	-82.833133	pH 7.2	
Arundinaria gigantea	34.985283	-82.832783	pH 7.2	
Chimaphila maculata	34.985383	-82.83275	pH 7.2	
Hydrangea radiata	34.9854	-82.83275	pH 7.2	
Solidago	34.987633	-82.83265	pH 5.5	
Erigeron pulchellus	34.988	-82.832833	pH 5.5	
Hexastylis	34.988533	-82.83275	pH 5.5	
Corylus americana	34.98927	-82.83287	pH 5.5	
Agrimonia	34.98941	-82.83270	pH 5.5	
Symphiotrichum patens	34.98936	-82.83353	pH 5.5	
Vernonia novaboracencis	*34.98936*	-82.83353	pH 5.5	
Juglans nigra	34.98936	-82.83353	pH 5.5	
Some Asteraceae	34.98936	-82.83353	pH 5.5	

3.3 Table – Plants collected, March 9, 2012

Plants collected at Kathy Bridge's property in Eskew Springs, near Oconee State Park, March 9, 2012

Xanthorhiza simplicissima	34.916117	-83.052867		(2012-0285)
Leucothoe fontanesiana	34.916117	-83.052867		(2012-0286)

3.4 Table - Collected plants with accession numbers and garden locations

2011-0239	*Magnolia*	*fraseri*	Fraser magnolia	Magnoliaceae	cove forest
2011-0240	*Actaea*	*racemosa*	Black Cohosh	Ranunculaceae	cove forest
2011-0241	*Lindera*	*benzoin*	Spicebush	Lauraceae	cove forest
2011-0242	*Mitchella*	*repens*	Partridge berry	Rubiaceae	cove forest
2011-0243	*Hamamelis*	*virginiana*	Witchhazel	Hamamelidaceae	cove forest
2011-0244	*Calycanthus*	*floridus*	Sweetshrub	Calycanthaceae	cove forest
2011-0245	*Eurybia*	*divaricata*	white wood aster	Asteraceae	cove forest
2011-0246	*Tiarella*	*cordifolia*	Heart-leafed foamflower	Saxifragaceae	cove forest
2011-0247	*Sanguinaria*	*canadensis*	bloodroot	Papaveraceae	cove forest
2011-0248	*Helianthus*	*glaucophylla*	white leafed sunflower	Asteraceae	cove forest
2011-0249	*Adiantum*	*pedatum*	Maidenhair fern	Pteridaceae	cove forest
2011-0250	*Athyrium*	*asplenioides*	southern Lady Fern	Dryopteridaceae	Cove forest
2011-0251	*Botrychium*	*biternatum*	Southern grapefern	Ophioglossaceae	cove forest
2011-0252	*Deparia*	*acrostichoides*	Silvery glade fern	Dryopteridaceae	cove forest
2011-0253	*Euonymus*	*americanus*	Hearts-a -bustin'	Celastraceae	cove forest
2011-0254	*Onoclea*	*sensibilis*	Sensitive fern	Dryopteridaceae	cove forest

2011-0255	*Polystichum*	*acrostichoides*	Christmas fern	Dryopteridaceae	cove forest
2011-0256	*Thelypteris*	*novoboracensis*	New York fern	Thelypteridaceae	cove forest
2011-0257	*Phegopteris*	*hexagonoptera*	Broad Beech fern	Thelypteridaceae	cove forest
2011-0279	*Pleopeltis*	*polypodioides*	Resurrection fern	Polypodiaceae	cove forest
2011-0280	*Goodyera*	*pubescens*	downy rattlesnake plantain	Orchidaceae	cove forest
2011-0281	*Euonymus*	*obovata*	Running strawberry bush	Celastraceae	cove forest
2011-0282	*Osmunda*	*cinnamomea*	Cinnamon Fern	Osmundaceae	cove forest
2011-0283	*Decumaria*	*barbara*	wood ramp	Hydrangeaceae	cove forest
2011-0284	*Prenanthes*	*altissima*	Tall rattlesnake root	Asteraceae	cove forest
2011-0285	*Athyrium*	*asplenioides*	Southern lady fern	Dryopteridaceae	cove forest
2011-0286	*Magnolia*	*fraseri*	Fraser Magnolia	Magnoliaceae	cove forest
2011-0287	*Kalmia*	*latifolia*	Mountain laurel	Ericaceae	cove forest
2011-0288	*Vaccinium*	*pallidum*	Blue Ridge blueberry	Ericaceae	cove forest
2011-0289	*Sassafras*	*albidum*		Lauraceae	cove forest
2011-0290	*Symplocos*	*tinctoria*	commonsweetleaf	Symplocaceae	cove forest
2011-0291	*Lobelia*	*syphilitica*		Campanulaceae	cove forest
2011-0292	*Halesia*	*tetraptera*	Mountain silverbell	Styracaceae	cove forest
2011-0293	*Eupatorium*	*perfoliatum*	common boneset	Asteraceae	cove forest
2011-0294	*Prosartes*	*languinosa*	Yellow fairybells	Liliaceae	cove forest
2011-0295	*Arundinaria*	*gigantea*	Giant cane	Poaceae	cove forest
2011-0296	*Chimaphila*	*maculata*	striped princes pine	Ericaceae	cove forest
2011-0297	*Hydrangea*	*radiata*	Silverleaf hydrangea	Hydrangeaceae	cove forest
2011-0298	*Erigeron*	*pulchellus*	Robins plantain	Asteraceae	cove forest
2012-0285	*Xanthorhiza*	*Simplicissima*		Ranunculaceae	creek by stevens creek area
2012-0286	*Leucothoe*	*Fontanesiana*	*Dog hobble*	Ericaceae	Creek by Stevens Creek

3.5 Table - Project BudBurst Data

Date: March 9, 2012. Site: Eskew Springs	
Xanthorhiza simplicissima	First Flower
Leucothoe fontanesiana	First Flower
Date: April 17, 2012. Site: South Carolina Botanical Garden	
Cornus florida	Fruit (Early)
Acer rubrum	Leaves Unfolding (Early)
Liriodendron tulipifera	Leaves Unfolding (Middle)
Magnolia grandiflora	Flowers (Middle)
Achillea millefolium	Flowers (Early)
Trillium grandiflorum	Flowers (Middle)
Taraxacum officinale	Flowers (Middle)
Fragaria virginiana	Flowers (Early)

Information for Botanical Garden sign (example, written by Lauren Duncan)

Common name: Yellowroot

Scientific name: *Xanthorhiza simplicissima*

Family: Ranunculaceae

Yellowroot is a plant commonly found in the upstate of South Carolina in mountainous areas. It likes shady and moist acidic soils in habitats along stream banks and woodland. This plant is known for its bright yellow root that contains the alkaloid berberine which is an astringent chemical that holds many medicinal purposes popular in local folklore.

Students' Reactions

Jessie Brown, an Ag Ed major, took the class to add to what she claimed was a limited background in horticulture and because she thought it would be a "neat way to learn about South Carolina's native plants and to also gain hands on experience that I would be able to use when I teach." She belittled her own contributions in the field (she did in fact contribute a great deal), but said she liked the opportunity to apply the knowledge she had gained in Plant Propagation the year before, and that she most enjoyed mounting the herbarium specimens. She liked the fact that the class exposed her to things that she might not otherwise have seen, and concluded, "I am also really excited that when I become a teacher and I bring my students on trips to Clemson for various events, I will be able to take them to the SC Botanical Garden and show them a collection that I had a part in starting."

Emily Harrington wrote up a concise description of the work she did, starting with researching the plants she intended to collect (she used the USDA PLANTS database and the University of Texas Wildflower Center) and making note cards that included photos and propagation information for each plant. She described collecting the plants and the data, including several ferns with Tom Goforth, placing the plants in cold storage over the weekend, meeting her partner Tobbi Stewart at the garden on Monday to repot the plants for winter dormancy, and giving the seeds she collected to Ryan Merck to propagate in the garden's nursery. She concluded by describing the process of mounting herbarium specimens. She wrote that she had had no previous experience identifying woody plants and now appreciates them more after seeing them undisturbed in their native habitat. She also learned of the importance of data collection, discovered how complex and tedious seed stratification can be, and learned that "orchids have a symbiotic relationship with a fungus that must be present in the soil to germinate."

Lauren Duncan, a horticulture major with more botanical experience than Jessie and Emily, had taken Dr. McMillan's Plant Taxonomy class the year before but observed that her plant identification skills were tested on the collection trip. She greatly appreciated Tom Goforth's participation; Mr. Goforth knows a great deal about the ecology and geology of the area, and was especially helpful at identifying different fern species. She also looks forward to visiting the Botanical Garden and seeing her contributions to the plant collection in the future.

Tobbi Stewart, the oldest of the undergraduates, took it upon himself to collect acorns from the Bur Oak on campus, and oversaw the process of cold stratification and planting them in the greenhouse. He did a very thorough job of researching the plants were proposed to collect in the field and created a Powerpoint that summarized their propagation needs. Stewart remarked that he would have participated in this project even if he had not gotten course credit for it because he enjoyed working on something real with lasting results.

DISCUSSION

Plant collection is the foundation of the modern field of botany. The men who explored the natural world in the 17th through 19th centuries collected plants everywhere they went, as seeds or living plants and as herbarium specimens. Carl Linnaeus, the father of scientific nomenclature, named around 9000 plants, most of them based on herbarium specimens collected in the field by other botanists ("Linnean Society" 2013). Businessmen in Europe funded expeditions to the Americas and Asia with the express purpose of having new and unusual plants sent back to Europe. Explorers such as Mark Catesby, André Michaux, and William Bartram were both scientists and nurserymen, searching the wilds of the Americas for potential ornamental plants that could become horticultural blockbusters. Catesby, for example, claimed to have introduced the Catalpa tree to the settled parts of the Carolinas and also to England (McMillan et al. 2013). Many of these collected plants ended up in botanical gardens, which for the past two centuries have deliberately introduced, acclimatized, and cultivated foreign species for horticultural and commercial purposes (Hulme 2011a).

The students in this Creative Inquiry followed in an old tradition of horticultural exploration, seeking out wild plants for the express purpose of placing them in a managed garden. In this, our students were much like John Lawson and Mark Catesby, who gathered living and preserved plant material and then sent it on to others. Lawson, for example, mailed his dried plants to the London apothecary James Petiver, who collected and organized "natural curiosities" from a number of contributors. Hans Sloane purchased these materials after Petiver died, which is how Lawson's herbaria ended up in the Sloane Herbarium (Bellis 2009). Catesby likewise sent masses of plant material to England, where Sloane, Dillenius, and others organized his contributions according to their own methods (Stephen Harris, pers. comm, 2012). The collectors' contributions remain valid, but their work has since passed through many other hands. These students likewise invested their time and effort into a project that they then handed off, not knowing the fate of their collections.

A Logistical Challenge

It is easy to say that these people "collected plants and introduced them to Europe." It is something else entirely to understand the logistics of this enterprise. What was involved in collecting all those plant materials, and how on earth did 18th and 19th century travelers get their plants all the way to Europe – still alive? Seeds are one matter, but not all seeds keep for long (magnolias, for example, do not), and not every plant is best propagated from seed. And how did the explorers know what they were collecting? (Sometimes they did not; Michaux ("Michaux" 2013), for example, complained bitterly that John Fraser had terrible plant identification skills and wasted a great deal of time collecting common plants and ignoring rare ones.)

There is also the matter of collecting data in the field and integrating it into larger datasets at the institution. Part of the purpose of this Creative Inquiry was to develop methods that the SCBG can use in future collections development, collecting provenance information along with the identities of plants. Provenance information is crucial for a scientific or conservation collection, as are herbarium vouchers that correspond to living material in the garden. With good provenance information that allows scientists to revisit collection sites, a garden could contribute to research on geographic distribution, the effects of climate change on migration, or levels of variation within a population (Pyke and Ehrlich 2010).

Collectors must also follow sound collection practices. These can include taking specimens from a range of sites, not taking too many plants from any one location, securing the necessary permits or permission, and ensuring that no endangered species are collected or accidentally harmed. (Hohn 2008) Collecting for ecological restoration requires attention to local adaptations and genetic variety (Vander Mijnsbrugge, Bischoff, and Smith 2010).

We discovered what generations of other plant collectors have discovered: collecting plants and data in the field poses many challenges. The collector must consider the following things:

1. When and where to collect. Where do particular plants grow? What season is the best for collecting? Spring ephemerals, for example, have completely disappeared by autumn so can't be collected then.
2. Plant identification, including both knowing what plants are worth collecting and identifying them in the field.
3. Simple logistics. How is the team going to get plants out of the ground and back to the truck and then to the garden? How will the team carry a shovel, a clipboard, 50 plastic bags, four large plastic crates full of plants, and a rock with a resurrection fern on it from the top to the bottom of a mountain without killing anyone?
4. Plant propagation. Every plant has different propagation needs, and wild plants can be particularly challenging. The students found that the Internet was the most valuable source for collection and propagation information; individual blogs are often a great resource for information on collecting and cultivating specific taxa. The goal is to have the plants survive and thrive in their ultimate home in the garden; but getting them there can take months, and can be traumatic.
5. Data organization, keeping data straight from the field to the nursery mat to the herbarium to the living collection.

All of these considerations are suitable for undergraduate education. In fact, because this type of plant collection is somewhat forgiving, with several opportunities along the way to correct mistakes, it is ideal for groups that might not have perfect field botanical skills. As long as the group is not collecting threatened or endangered species and follows good collection procedures, not collecting too many plants from one site, undergraduates can safely collect plant materials for the garden without unduly harming the ecosystem of the collection site.

That being said, we certainly learned some lessons that could be used to improve future classes of this type. For example:

Identifying plants is hard! There were several taxa we could identify only by genus (*Carex*, *Hexastylis*), and one composite that ended up with the overly vague determination "Asteraceae." Some *Magnolia fraseri*, though confusions for which I take full responsibility, ended up tagged *Magnolia macrophylla.* Printed field guides are heavy and clumsy; electronic devices do not receive signal in the mountains, and need clean hands. We could conclude that collecting plants with a group of undergraduates will inevitably lead to inaccuracies, which is almost certainly true. But that does not necessarily mean that mixed groups should not collect; I doubt seriously that we are the first or only group of collectors to make mistakes, and field botanists who can identify every plant perfectly are rare indeed. The important lesson here is that data will have to be refined and corrected after the field work is done; keep good records, and double check everything back on campus.

A narrowly focused plan can result in more efficient work and a better collection more suited for the garden's needs. Our autumn collection trips, while exciting and productive, were based on an extremely long wish list of plants and resulted in a fairly broad collection of plants – this was useful for the initial planting of the Natural Heritage Garden, but would produce too many random taxa for a more specific planting. The spring trip to collect large amounts of two specific taxa with destinations in the garden already prepared went much more efficiently, and the students enjoyed the confidence that they were getting exactly what was needed.

Collecting thorough scientific and provenance information takes a long time. There is no way to rush the process of recording GPS and soil type and choosing an herbarium specimen at the time of collection, and then recording that information in the garden's database and preparing the voucher.

Small groups are most likely best for this type of work. This project works as an independent study, but probably would not be practical for a full-size class. A large class would prevent the close supervision necessary to make the work productive, and a large group could do a great deal of damage to the collection site.

Citizen Science

Another purpose of this Creative Inquiry was to explore the use of undergraduates or other interested amateurs to collect scientific data of various types. Botanical gardens and other institutions have recently begun using volunteers to “crowd-source” the collection of data. Citizen science is an area with vast opportunities for research involving collaboration with the public. The general public can collect data on plant phenology, invasive species, and restoration projects. The scientific value of the data might make itself evident only after a long time, but citizen data can eventually produce large and useful data sets (Donaldson 2009a).

The Chicago Botanic Garden runs its Plants of Concern project with several hundred citizen volunteers who collect data on the Chicago Wilderness region’s rare plants. (Bianca Rosendorn 2010). Some botanic gardens use citizen volunteers to track phenological changes in garden plants (Primack and Miller-Rushing 2009). The USA National Phenology Network currently collects a huge amount of phenological data through a network of citizens, universities and schools, government agencies, and other groups. The USA-NPN also runs a Cloned Plants Project in which observers plant a cloned lilac and record data on its phenology (“USA National Phenology Network” 2013).

Citizen science provides two big benefits to science and botanic gardens: it allows the collection of much larger datasets than would be possible with only professionals gathering data, and it gives private citizens a sense of ownership of scientific discovery. The large dataset offsets the inevitable inaccuracies that can be introduced by amateur data collectors. Botanic gardens and other natural history collections must constantly strive to improve their "relevance;" using citizen scientists to perform research increases the ecological and environmental value that collections can offer, and makes relevance much more obvious by making private citizens part of the workforce (Pyke and Ehrlich 2010).

The Creative Inquiry students' work with Project Budburst gave them experience with independent research and field observation and plugged them into a scientific body that was not in any way associated with Clemson University, a valuable lesson in the wider world of scientific research. The students enjoyed contributing data to a very large project. They also used the garden for actual scientific research, choosing plant's in the garden's collection for their observations. They will thus think of the garden as a place where people do "science," not just as a pleasure garden.

Creating Stakeholders

University botanic gardens have a different set of stakeholders from non-academic public gardens. Groups of people with legitimate interests in university gardens include students and faculty who engage in education and research, the local horticulture industry, and members of the local community who visit the garden for recreation and education. Gardens can cultivate all of these relationships with an eye to future financial and volunteer support. Engaging students who will become alumni is particularly valuable. Horticulture students may end up working in the local horticulture industry. Students who do not go into the horticultural field can be valuable sources of support (Scoggins 2010).

CONCLUSION

The students' own comments reveal the value of this type of learning experience. All of them appreciated the chance to do "real" work that produced a real product; when these students visit the Cove Forest display in the Natural Heritage Garden, they can see plants that they themselves gathered. They liked applying knowledge gained from other classes to actual work. They especially enjoyed the chance to go out into the field and to see "nature" in action, an increasingly rare experience for students today. They got to collect data and consider how future researchers might use it. And they might just have learned that not all scientific work is precise and clean, and not everything is known about every topic. If they came away having realized that museums and reference books do not contain the sum total of the world's knowledge and that scientists are just ordinary people who happen to be obsessed with collecting data, the value of which they may or may not be able to explain, they will have learned something real.

Benefits to students

1. Real-world practical experience that uses their skills in plant identification, ecology, and plant propagation to meet a real need of the SCBG

2. Scholarly experience in considering the philosophy behind botanical gardens and collecting scientific data
3. An opportunity to do field work, increasingly rare for today's students
4. Practice in doing independent research and practical work - handling collected plants, preparing herbarium specimens, field checking plants for Project BudBurst

Benefits to SC Botanical Garden

1. Plants added to living collection, with provenance data
2. Use of garden for teaching and research
3. Investing in future botanical garden supporters

It would be interesting to continue this project in the future. It has a great deal of potential for involving students in the work that botanists have done since the late 1600s. There are various possibilities for collection. For example, teachers and students might reconstruct the routes of various historical plant collectors – Catesby, Bartram, Gray, Michaux, Lawson – and then plan collection trips along those corridors to seek plants that remain in historical herbarium collections. This would be an excellent opportunity to introduce students to the ecology of this region, both through modern visits and historic descriptions. This sort of collection project could be integrated with the Botanica Caroliniana work (see Chapter 4: Expanding a garden in virtual space), perhaps adding blog posts and photographs to the website. There are many possibilities.

CHAPTER 4: EXPANDING A GARDEN IN VIRTUAL SPACE

There is a tremendous amount of scientific data out in the world. Primary source materials - say, dried plant specimens - are held in museums and herbaria throughout the U.S and Europe. This material is a treasure trove of unpublished data.

One way for natural history collection such as botanical gardens and herbaria to expand their influence is to enter into virtual space. The Internet opens up a vast array of possibilities and connections that were impossible a few years ago. Using digital imagery and digital collections, a South Carolina institution can now collaborate with institutions in other countries. It can also use computing to establish connections across time, so that scientists in 2012 can continue the work of scientists in the 1720s. This requires communication with curators of other collections, the securing of access and rights to images, and organization of data in such a way that it can be used freely and easily. It also requires an openness to new possibilities and connecting the right people to the right data. But with the Internet, these connections are all possible, and not necessarily as complicated as they may appear.

This chapter describes work that Dr. McMillan and I have done with Mark Catesby's herbarium collections. [1] Catesby essentially did a field survey of South Carolina in the early 1720s, before Europeans had explored and settled the state. Catesby's specimens still exist, but largely unpublished. Our project involved taking digital photographs of Catesby's collection at the Sloane Herbarium in London, posting them online, and analyzing the material. Our work illustrates the potential of this type of material and the value of making it available to scholars who know how to use it.

INTRODUCTION

Mark Catesby is best known for his *Natural History of Carolina, Florida, and the Bahama Islands*, the first English-language work to describe the natural history of a region of the Americas. Catesby did his field work in South Carolina and the Bahamas in

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[1] This chapter describes up this project in the context of this particular doctoral dissertation. The full Botanica Caroliniana project is available online at http://folio.furman.edu/botcar. For a peer-reviewed scholarly treatment of the Sloane materials, see our article: McMillan, P.D., A.H. Blackwell, C. Blackwell, and M.A. Spencer. 2013. The vascular plants in the Mark Catesby collection at the Sloane Herbarium, with notes on their taxonomic and ecological significance. *Phytoneuron* 2013-7: 1–37.

the 1720s and used his observations and collections to create both text and images for his book.

Catesby was born in England on March 24, 1682 or 1683, and studied natural history in London as a young man. In 1712 he made his first trip to America, visiting his sister and her husband in Virginia. He stayed in Virginia for several years, collecting and sending plants to England, and visiting Jamaica in 1715. After returning to England in 1719 he met Sir Hans Sloane, President of the Royal Society and of the College of Physicians. With financial backing from Sloane, William Sherard, Charles Dubois, and several others, Catesby sailed to "Carolina" in 1722 under orders to study the plants native to the region (Allen, 1937). During the next four years he periodically sent dried and living plant specimens to his patrons in England. He spent at least nine months in the Bahamas in 1725 and 1726, and then returned to England in 1726.

The *Natural History*

Back in England, Catesby immediately began work on his *Natural History*, doing his own painting and engraving. He published the first portion of the *Natural History* in 1729 and periodically added sections to it until he completed it in 1747 (Reveal 2012). He was elected a fellow of the Royal Society in 1733 on the strength of his first volume on American plants and animals (Allen 1937).

The two volumes of the *Natural History of Carolina, Florida, and the Bahama Islands* include 220 engraved plates depicting plants and animals that Catesby found. In the text, Catesby describes the people and places he encountered, including collection trips into the “upper parts” of the country, toward the mountains, during which he employed a Native American to carry his box of painting materials and dried plant specimens (see *Natural History*, 1-8). For each plate, he provided a description of the species in question, including size, habitat, and traditional uses when known.

Carl Linnaeus cited a number of Catesby’s plates whilst describing some North American species and varieties in his *Species Plantarum*. Although other subsequent botanists referred to some of Catesby’s herbarium specimens in their work, Linnaeus appears not to have examined Catesby’s actual dried plants (Dandy 1958).

Since that time, other scholars have avidly studied the *Natural History,* both plates and text, but the Sloane specimens have been comparatively neglected. Until we began this project, there had been no comprehensive publication of recent determinations of the specimens. What research has occurred has focused on taxa that appear in the *Natural History*. Richard Howard, former director of the Arnold Arboretum, visited the Sloane Herbarium in 1982 to verify the identities of specimens in H.S. 212 and H.S. 232 that appear in the Natural History (Howard and Staples 1983). James Reveal revisited the *Natural History* in 2009, comparing the plates with Catesby’s original watercolors, currently held in the Royal Library at Windsor Castle, England, to further refine the determination of plant species (Reveal 2009).

Mark Catesby, saint or scientist?

Catesby still attracts many fans today, some of whom display an almost fetishistic hero-worship of the man. The Catesby Commemorative Trust (www.catesbytrust.org), for example, exists solely to uphold the memory of Mark Catesby and his work. In November 2012, this Charleston-based organization held a week-long conference celebrating the third tercentennial of Catesby's arrival in Virginia in 1712 and celebrating his impact on the world. They brought in various speakers to describe Catesby's various activities and the history surrounding him and traveled from Richmond to Washington, D.C., to Charleston to discuss Catesby's influences, art, science, and influence on natural history. A highlight of the trip was the opportunity to view several first editions of the *Natural History*, which the group seemed to regard almost as holy writ.

But what about Catesby's primary sources, his dried plant specimens? Catesby's botanical illustrations and published text are all very well, but they are not the sum of the man's work. Catesby also left behind about 2000 dried plant specimens. Beautifully pressed and preserved, they still exist – unpublished until now.

Botanical illustration vs. herbarium specimens

Catesby's botanical illustrations are masterpieces of information technology and represented the state of the art in 18th-century scientific visualization. Through his color plates and printed publication, Catesby could disseminate his scientific observations to a wide audience. He could restore depth and color, texture and movement, juxtapose plants with the animals that eat them or nest in them, and paint environmental cues such as glimpses of ocean or stream. In so doing, he joined in a long tradition of botanical illustration that allowed for the creation of notional plants, including details that could never occur together in nature and thereby conveying a large amount of information in one image.

But it is a mistake to disregard Catesby's dried plant specimens. The dried specimens ironically still represent the state of the art in botanical taxonomy, which continues to rely on herbarium specimens for vouchers and types. Catesby and his herbarium curators created these specimens for an audience of scientists. The dried plants are "real" in a way that the painted illustrations can never be. There is no artistic license in adding or subtracting details; the only artistry involved is in the presentation of the objects on the page. Because of this enforced honesty, the dried specimens still contain details that botanists can use to distinguish between species, such as length of petioles or number of petals.

PROBLEM: ACCESS

The problem with the dried specimens is that they are in England. Catesby sent some of his herbarium specimens from the Carolinas, Georgia, and the Bahamas to Sir Hans Sloane. These formed part of the original collections of the Natural History Museum in

London. Catesby sent others to Sherard; these are currently housed in the Sherard and Dubois herbaria at the University of Oxford (Reveal 2012)[2].

How can a scientist from South Carolina examine these collections? Until 2012, the only way to see the Sloane materials was to visit London, contact the curator of the Sloane Herbarium, and view them on the premises during business hours. None of the collections had been systematically identified or published. (The Oxford materials have recently been photographed and displayed online (Harris 2013); they can be accessed here: http://herbaria.plants.ox.ac.uk/bol/catesby.)

Ignoring Catesby's primary sources is a loss to science. Catesby's published material is excellent, of course, but his herbarium specimens are as useful as primary source data today as they were 290 years ago, or perhaps more so because botany and ecology have advanced.

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[2] Catesby sent the specimens currently housed at Oxford University to Sherard, who organized their mounting and storage. Catesby also corresponded with Dillenius about the specimens after Sherard's death; the letters are stored in the Oxford University Department of Plant Sciences along with the herbarium specimens.

METHODOLOGY

In November 2011, Dr. McMillan and I went with my husband, Dr. Christopher Blackwell, to the Natural History Museum, London, to photograph herbarium specimens in the Sloane collections. This project was part of Chris' ongoing process of research in longitudinal alignment of image collections, supported by National Science Foundation Grants No. 0916148 & No. 0916421. Working with Mark Spencer, curator of the Sloane Herbarium, we photographed all the Carolina materials we could find in the collection – Mark Catesby, John and William Bartram, John Lawson, the so-called Walter Herbarium, and some specimens collected by Robert Ellis and James Oglethorpe.

As the grant funding the digitization project requires, all of these photographs are held under a Creative Commons license ("Creative Commons" 2013), which means they are freely available for all non-commercial uses. In 2012 we posted the Catesby specimens and some of the Bartram images online on our site: *Botanica Caroliniana* (C. Blackwell and Blackwell 2013). That site contains a link to a world-readable archive of all the image data, which anyone is free to download, mirror, and re-purpose according to the terms of the Creative Commons license.

Determinations

The Sloane collections can be difficult to work with because they predate binomial nomenclature and modern geography. Few of the specimens have been identified with modern scientific names. Making determinations requires very good botanical skills and more than a passing familiarity with the flora of the region. Dr. McMillan is one of the few people with those skills. An expert in the field botany of South Carolina, he can make quick work of identifying plants from this region, even three-century-old preserved specimens with absolutely no identifying information. Having the specimens readily available online made it possible for him to make a complete set of determinations of the Sloane collections.

In December 2011 Dr. McMillan and I worked our way through the images from the two Catesby volumes, H.S. 212 and H.S. 232, identifying all the vascular plants from the Carolinas. We could access the entire Sloane collection at once and revisit specimens as often as we liked, zooming in on small details as necessary. Using the Internet in conjunction with a searchable PDF of Alan Weakley's *Flora of the Carolinas* (2011) facilitated the process of identification. The fact that the images are online allows us to revisit them as many times as we wish, to zoom in on details, and to compare specimens to one another and to the digital images of Catesby's *Natural History*.[3]

[3] Reveal's own recent work is a good illustration of the value of digital collections; in his 2009 article he lists a number of digital publications of Catesby's work and Linnaean type specimens that assembled a huge amount of far-flung documents online and made possible a project that even just a few years earlier would have been prohibitively difficult if not impossible (Reveal 2009).

Adding the Oxford Collections

Catesby sent plant specimens to Oxford as well as to London. The Oxford Herbaria house over 800 herbarium specimens attributed to Catesby. Including these in the list of determinations would give us a nearly complete set of the taxa that Catesby collected. (James Reveal has mentioned to me the existence of other specimens in a box in the Sloane Herbarium; perhaps there are other unknown specimens in both historic herbaria or other locations.)

In May 2012, with the generous help of the Wade Batson Scholarship in Field Botany, I traveled to Oxford, England, to visit the herbaria there. I met curator Stephen Harris and viewed a number of the historic specimens in that collection. Harris has put digital photographs of these collections online and identified a number of them, though in many cases his determinations were only to family or genus level (Harris 2013). Dr. McMillan and I have analyzed these images and giving them more precise determinations, in accordance with Weakley's current flora. A publication of the complete Catesby collection would be an obvious outcome of this work. It would also be useful to incorporate the Oxford images into the Botanica Caroliniana database; that will require further negotiation with Oxford.

RESULTS

My collaborators and I have written an article on these plants and the project that published in *Phytoneuron* in January 2013. This article publishes a list of determinations of all the vascular plants in the collections that were most likely from Carolina along with observations on ecology, taxonomy, and historic botany, as well as a discussion of the value of digitization and online publication (McMillan et al. 2013).

What are some of the things we discovered from Catesby's plants? Some specimens provided clues to Catesby's likely route from Charleston to the Upstate. Others suggested that certain species were growing in South Carolina before European settlement. For example, Catesby collected several specimens of *Catalpa bignonioides* Walter, a species with a native range thought to be well south of the Carolinas. Likewise *Acer saccharinum* L., which Alan Weakley claims is "rare and mostly introduced east of the Appalachians and south of Virginia" – yet a specimen appears in Catesby's Sloane collections. We learned that Catesby had an eye for rare and distinctive plants, that he must have sought out a range of diverse habitats, and that he was interested in economic and medical uses of plants by both Europeans and native Americans. There is further commentary in our article and in various blog posts on the Botanica Caroliniana website.

One really exciting aspect of this work is that it ties together data along a temporal axis as well as a geographic one. Catesby conducted a field survey in this state 290 years ago. Because he preserved his specimens carefully, we can study them today and see the same features his contemporaries would have seen. That makes Catesby our research partner.

As I see it, our work with Catesby isn't "historic botany." It's just botany. We are continuing Catesby's work with plant specimens, using his primary source material to do taxonomic work he could not do himself. (Catesby predated Linnaeus – he couldn't attach binomials to his specimens because they didn't exist yet.) It would almost be appropriate to include Catesby as an author, if not for the fact that he is not in a position to voluntarily take responsibility for our work as well as his own.

Parallels with *Natural History*

Many of the species that Catesby illustrated in the *Natural History* are represented as herbarium specimens in the Sloane collections. Scholars who have visited the Sloane in previous decades were often most concerned with these particular specimens because of their connection to Catesby's publication. No one, however, has ever published side by side images of *Natural History* illustrations with their corresponding herbarium specimens.

Digital publication makes this process easy, and frankly it was an obvious thing to do. Richard Howard identified specimens corresponding to *Natural History* pages back in 1982. I collected these particular images on their own webpage (http://folio.furman.edu/projects/botanicacaroliniana/Parallels.html), placing them alongside the corresponding images from the *Natural History*. Now it is easy to see herbarium specimens side-by-side with drawn and painted illustrations (C. Blackwell and Blackwell 2013).

Longitudinal Scholarship

The metadata on the pages of H.S. 212 and H.S. 232 includes various labels added by other scholars over the past three centuries. Sloane's handwritten notes, placed around the late 1720s or 1730s, refer back to John Ray, who published his history of plants between 1686 and 1704. Solander's labels, added in the 1760s or 1770s, incorporate some Linnaean identifications and show Solander's own efforts at independent identifications. In 1982 Richard Howard, Harvard botanist and director of the Arnold Arboretum, visited the Sloane and added typewritten labels containing modern identifications to the specimens that corresponded to plates in the *Natural History*. In 1992 James Reveal contributed his own labels for the Linnaean Plant Name Typification Project. Along the way other scholars added notes in pencil. This metadata could provide ample material for further scholarship in both historical botany and its relationship to modern ecology.

Previous scholars placed their notes directly on the folio pages. If they had not, their contributions would not be available to us today. We hope, however, that our contributions to this ongoing discussion will become part of the record despite the fact that we are posting them online instead of pasting them into the volumes in London. This is one of the main purposes of our project – to expand the scope of analysis of these historic specimens and allow for many interconnected observations and debates without having to interfere with the physical artifacts.

Catesby's legacy and science today

Digitizing Catesby – freeing up this huge dataset – has thus allowed several scientific developments that were not possible in 2010. To sum up what we have done in the course of a year:

1. We have created and published a set of data that has existed but been relatively inaccessible since the 1720s.
2. We have put this dataset into the hands of scholars who can realize its potential
3. We have analyzed a field survey of the state done in 1723-1725, giving us information about plants that were growing here before the state was settled and continuing the work of an earlier scientist
4. We have published side-by-side images of scientific specimens and artistic expressions of the same taxa created by the same individual

None of this was possible before the Internet. Now that the Internet exists, it is perverse to try to work without it, and silly to fail to exploit the potential offered by digital photography and instantaneous data-sharing.

DISCUSSION

Biological collections, including herbaria, have huge potential for research in systematics, ecology, and evolution (Pyke and Ehrlich, 2010). Donaldson (2009) identifies herbaria as an area on which botanical gardens should focus their research efforts. Researchers have used herbaria to track the spread of species and for phenological changes that could indicate a changing climate (Primack and Miller-Rushing 2009); to monitor the movement of invasive species (Aikio, Duncan, and Hulme 2010); to study phylogenetic variation and past geographic distribution of crop landraces (Lister, Bower, and Jones 2010); and to reconstruct the population structure and extinction risk of plant species (Rivers et al. 2010). Projects such as this one are a good way for a garden director to showcase his own scholarship and integration of collections and research (Albrecht 2010).

Lack of access

Lack of information and lack of access hampers research in natural history collections. Herbaria are typically not well documented (Bebber et al. 2010). The best information on the Sloane Herbarium to date has been Dandy's *The Sloane Herbarium*, published in 1958. Information sharing through databases is essential if biological collections are to reach their true potential and to become relevant to the general public (Pyke and Ehrlich 2010).

With traditional methods of herbarium and library storage, only a user who can visit an herbarium or borrow specimens can examine them. Everyone else must trust that that scholar's interpretation of what he saw was correct. This has long been the case with Catesby's materials, which have been periodically examined by eminent scholars but never published. The *Botanica Caroliniana* project aims to address this deficiency by making collections available to any user, anywhere, at any time.

We are of course grateful that Catesby sent his specimens to London, where they have survived in good condition for nearly three centuries. The actual objects will always be valuable, and we are certainly not suggesting that photographs can replace the dried plants themselves. But it makes sense for South Carolina botanists to have access to South Carolina plants. Putting these specimens in the hands of Patrick McMillan, an excellent taxonomist, and then sharing the data with the entire community of Carolina botanists will produce much more scientific discovery than would be possible if scholars had to visit London to work with these materials.

Botany lagging behind in digitization

Botany has failed to keep up with some other scientific disciplines in embracing digitization and creating digital libraries. Digital publication allows for immediate sharing of data with a much larger audience than print publication, and can make much larger bodies of data accessible to many more people. With electronic publication, there is no physical reason why articles cannot appear as soon as they are complete. Other fields such as medicine, chemistry, and physics have embraced online publication and pre-print access to articles, and the biological sciences allow online, peer-reviewed, open access publication. Botany, however, has lagged behind, so much so that Brach and Boufford (2011) published an article in 2011 – year before last – asking why, exactly, botany still insists on publishing paper flora. (I will here thank Alan Weakley for making his *Flora of the Carolinas* (2011) available online as a searchable pdf; Dr. McMillan and I found it invaluable in our work with the images of Catesby's specimens.)

My own experience attempting to publish our Catesby piece in a traditional botanical journal (*Castanea*) was discouraging. My research partners and I had data and analysis ready to publish in early 2012. We had already posted all the images of the Mark Catesby specimens online, freely available for all non-commercial uses under a Creative Commons license (C. Blackwell and Blackwell 2013). And yet we were forced to wait months for editorial review, and many more months for actual publication. The editorial process itself was antiquated and wasted a great deal of time, both by reviewers who laboriously typed out edits such as "Line 1320: Move period to after '(Amira et al. 2012)'", and by authors who had to make these changes that could have easily been done by the editors. This gave me the impression that the journal had not kept pace with technological changes and was not likely to appreciate ground-breaking research that actually uses the tools that are now available to us.

There was also the matter of intellectual property. The traditional print journal demanded that the authors sign over copyright to our work to the journal, and this ultimately forced us to withdraw the manuscript. Aside from my own misgivings about relinquishing my rights to my own work, the Natural History Museum London recommended against signing this copyright agreement, which they believed would be in the interest of neither the Museum nor science (NHM, pers. comm 2012). I proposed to the journal editors that we could either place the article under a Creative Commons license, or possibly grant them a non-exclusive license to publish it. They declined both of these possible solutions.

In the interest of rapid publication and keeping on good terms with our London colleagues, I withdrew the manuscript on January 18 and immediately resubmitted it to *Phytoneuron*, a new online botanical journal that allows authors to retain copyright and promises quick publication. True to his word, editor and publisher Guy Nesom replied to my email within the hour, accepting the article for immediate publication. It was published online January 28, and in a digital format that promised to reach more interested readers than a traditional print/subscription model (McMillan et al. 2013).

Connection with SCBG

Historic botany certainly has a role to play in the botanic garden. Catesby has provided us with a field survey of plants growing in pre-settlement South Carolina. Dr. McMillan has used this data to create a new garden at the South Carolina Botanical Garden, the Mark Catesby historic garden. This garden will contain plants collected by Mark Catesby in the 1700s. Visitors will be able to see plants that were growing before the Europeans arrived, and see how they fit into the ecology of the region.

This work has also increased the visibility of the SCBG and Dr. McMillan's work there. On March 9, 2013, the public radio program Walter Edgar's Journal broadcast an interview with Dr. McMillan and me on the subject of Catesby's plant collections. This generated a certain amount of positive feedback, including an invitation for us to speak at the annual meeting of the St. George Tucker Society in Augusta, GA, that August. I have written an article for a consumer publication, the SCDNR magazine *SC Wildlife*, which will appear in the summer or fall and should generate more positive attention for the SCBG and for Clemson.

CONCLUSION: FUTURE PROJECTS

This chapter focuses on Mark Catesby because that was the first collection of digital images that Dr. McMillan and I addressed. We chose him because of his historic significance, with his *Natural History*, and because his collection indisputably pre-dated large-scale European settlement.

That leaves us several other sets of images to explore. We photographed all the materials we could find from the Carolinas, which included the herbaria of John Lawson, both Bartrams, Thomas Walter, and odds and ends from a few other collectors. All of these contain the potential for new discoveries and scientific analysis. Lawson's materials are even older than Catesby's, and the herbarium volume is in much worse shape; we have yet to make determinations there. The later materials have been more thoroughly explored by other scholars but never yet completely published. They are now available for anyone who wants them. Joel Fry, curator of Bartram's Garden in Pennsylvania, has already examined many of the Bartram images.

Dr. McMillan and I would like to keep developing this collection of materials. André Michaux's collections are in Paris, and are also unpublished. Michaux was one of the most important botanists to explore the Carolinas; it would be very useful to bring his work into the Botanica Caroliniana collection so that Carolina botanists can examine it.

Some of this work might be suitable for crowd-sourcing, or using groups of students. Determining the identities of the plants in Catesby's collections was not a quick job; some specimens are easily identified at a glance (for example, *Quercus marilandicus* jumps out of the page), but most are not (for example, fragmentary Asteraceae or myriad Asclepiaceae). The process is time-consuming. But a crowd might make quick work of this job. If we were to place all images online with a wiki interface, it would be possible for interested viewers – students in a botany class, amateur gardeners, other scientists – to contribute their suggestions for determinations of specimens. If a qualified botanist reviews all determinations before publication, this could greatly reduce the amount of labor involved in identifying historic collections.

CHAPTER 5: PLANT SHARING AND CONSERVATION

Botanical gardens today emphasize their importance to plant conservation. This is of course one way of increasing relevance; there is no denying the massive biodiversity crisis facing the world, and plants are more definitely under threat. Habitat degradation, introduced invasive species, and climate change have adversely affected thousands of plant taxa. Botanical gardens have preserved a number of species in their *ex situ* collections, and many institutions are working hard to propagate and reintroduce species into wild habitats and to monitor wild populations. I discuss several aspects of plant conservation in botanical gardens in Chapter 1, including the debate over whether *ex situ* conservation is even possible.

This chapter considers *ex situ* conservation from a national and global legal perspective. In addressing this topic, I have moved away from South Carolina, and from the botanical garden housed at Clemson University. But the issues I discuss affect gardens of all sizes, and the outcomes of current debates could very well determine whether or not SCBG and other smaller institutions can make a useful contribution to plant conservation in the future.[4]

INTRODUCTION

Laws affect botanic gardens of all sizes, whether they realize it or not. State and federal laws determine what plants can be collected from the wild and where. International laws, treaties, and conventions place their own restrictions on the movement of plants, plant parts, and genetic materials. These restrictions affect the conservation of plants.

They also suggest a question: is plant conservation better served by restricting the movement of genetic materials or by permitting free sharing of genetic resources? To answer this question scientifically is beyond the scope of this dissertation. But I can present the debate as it currently stands, and suggest the direction that I believe would be the most productive.

This chapter describes the United Nations Convention on Biological Diversity, or CBD, which entered into force in 1993. The U.S. is nearly alone the world in having refused to

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[4] Much of the content in this chapter appears in similar form in my article "Botanical Gardens: Driving Plant Conservation Law," published in the *Kentucky Journal of Equine, Agriculture, and Natural Resources Law* in Spring, 2013 (A. H. Blackwell 2013).

ratify this convention. The CBD creates a concept known as Access and Benefit Sharing, or ABS, which dictates that nations that benefit from biological resources must share those benefits with the nations in which the biological resources originated. Every member nation is meant to create its own legal regime to stipulate terms of access and the sharing of benefits.

U.S. botanic gardens have been somewhat confused by this convention for the past two decades. Most gardens have taken no notice of the CBD; some have responded with their own institutional ABS policies. The American Public Garden Association (APGA) has been attempting to create a set of guidelines for U.S. institutions to follow. Not all parties agree on how best to handle this issue; some favor a highly restrictive regime, with thorough monitoring of the movements of germplasm, while others believe that the more material is shared freely, the more likely plants will be conserved.

These negotiations could have a serious impact on the work done by botanic gardens in the U.S. and abroad. The issues include intellectual property, ownership of genetic resources, open access, sharing of data and plant materials, and definitions of benefits. They go to the heart of this dissertation – how can a small institution participate in national and global plant conservation efforts? My own answer is that it can only do this if the rules are not too restrictive. Open access and free sharing, with a flexible definition of benefits and within a culture of collaboration, would permit the largest set of institutions to participate. And more participation is good.

CONVENTION ON BIOLOGICAL DIVERSITY (CBD)

The Convention on Biological Diversity (CBD) is an international convention established at the 1992 Rio de Janeiro UN Conference on Environment and Development. Member states agree to protect biodiversity in their own territories and to support the protection and sustainable use of biodiversity elsewhere. The United Nations Environment Programme (UNEP) created the CBD in response to threats to biodiversity of species and ecosystems by human activities. A group of experts worked on the convention from 1988 until 1992, when the CBD was opened at the 1992 UN Conference on Environment and Development in Rio de Janeiro, the “Earth” Summit. It entered into force on December 29 1993 (“CBD” 2013).

The U.S. signed this convention on June 4, 1993, but, along with Andorra and the Holy See is not a party to it. Every other recognized nation in the world is a party to the CBD. The U.S. attends meetings as an observer but cannot engage in negotiations or participate in final decisions. (See Snape 2010 for a thorough discussion of why the U.S. did not ratify the CBD when the rest of the world did, after championing the idea of a biodiversity treaty in the 1980s. Reasons included biotechnology industry fears that it would have to pay too much to use genetic resources and a general reluctance to use the USDA’s repositories to provide access to any user, any time, free of charge.)

The CBD aims to promote sustainable development and sustainable use of resources. Its objectives are the conservation of biodiversity, sustainable use of biodiversity, and fair sharing of the benefits of genetic resources and relevant technologies. States have the right to exploit their own natural resources but must ensure that their activities do not harm the environments of other states or areas. All parties are to cooperate with each other to manage areas beyond national jurisdiction. Every party must develop its own national strategies for preservation of biological diversity, including identification of important components of biodiversity, monitoring those components, and determining what activities could damage that diversity. Biodiversity should first be preserved *in situ*, and then *ex situ* as a complementary measure. Every party is encouraged to educate the public about the need to protect the environment. National governments hold the right to determine access to local genetic information, but all parties are supposed to share access to technology that makes use of genetic resources. All parties are to facilitate the exchange of biological information.

Specific to botanic gardens, Articles 8 and 9 cover *in situ* and *ex situ* conservation. Under Article 8, *in situ* conservation, each party is to establish and regulate protected areas, promote the protection of ecosystems and populations of species in natural settings, use sustainable development next to protected areas, restore degraded ecosystems, prevent the introduction and spread of invasive alien species, and protect indigenous lifestyles. *Ex situ* conservation, Article 9, is meant to complement *in situ* measures. Each party should create facilities for the *ex situ* conservation of and research on plants, animals, and micro-organisms and plan for the reintroduction of preserved species into the wild when possible.

Access and Benefit Sharing (ABS)

Article 15 of the CBD, Access to Genetic Resources, is the source of the legal basis for the principles of Access and Benefit Sharing. Under this article, signatories to the convention recognize that states have sovereign rights over their natural resources and can determine how natural genetic resources can be accessed (15.1). Every party to the CBD agrees to try to facilitate access to those genetic resources by other parties for environmentally sound uses and under mutually agreed terms. (15.2, 15.4) The party in whose territory the genetic resources are found must give informed consent to their use prior to any use of those resources unless the parties have come to another arrangement. (15.5). Ideally any scientific research done on genetic resources should take place in the country of origin; the country supplying the resources should at least be able to participate in the research. (15.6). Every signatory agrees to pass laws or regulations to guarantee that the results of research and the benefits of commercial use of genetic resources is shared with the countries providing the resources. (15.7).

Article 15 introduced several new principles to the rules governing research permits and licenses ("SCNAT" 2013):

1. Prior Informed Consent (PIC). The relevant national authority of the nation providing the genetic material must know about the collection and give its consent before any collection can take place.

2. Mutually Agreed Terms (MAT): Users and providers of genetic material must agree on the conditions governing use of that material and the sharing of any benefits gained from it.
3. Benefit Sharing: the country providing the genetic material must share in the benefits of the resulting research. Sharing need not be restricted to monetary benefits; it can occur through infrastructure building, technology transfer, and academic networks, all of which are necessary to building the knowledge bases of poorer nations.

"Genetic material" refers to any plant, animal, or microbial material that contains functional units of heredity. "Genetic resources" means genetic material of actual or potential value. (Article 2)

The term "access" is not officially defined in the CBD, which leaves it open to interpretation by individual countries. As it is interpreted, the term applies to genetic materials and the traditional knowledge involved in obtaining of using them. If research uses traditional knowledge (TK) or works with indigenous communities, the ABS system applies and the holders of the traditional knowledge must be included in the research process.

The purpose of the ABS system to equalize the imbalance in profits derived from the exploitation of biological materials. ("Biopiracy" and "bioprospecting" are terms that often appear in discussions.) Advances in genetic engineering in the 1970s and 1980s allowed advanced nations to develop genetic resources into commercially valuable products protectable as intellectual property. Developing nations in the global "South" tended to be the sources of the genetic resources while advanced nations in the "North" tended to create the profitable products. The profits generally stayed in the advanced nations, and the countries providing the genetic resources received few or no benefits from their unique biota. Developing nations protested that the genetic resources, the "common heritage," was turning into private property, and they demanded a share in the profits (Birhanu 2010).

Bonn Guidelines

In 2006 the Secretariat of the CBD adopted the Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising Out of Their Utilization ("CBD" 2013). The purpose of the Bonn Guidelines was to assist stakeholders in developing practical guidelines and strategies for ABS, with particular emphasis on users seeking PIC from providers. The guidelines are not legally binding, but Executive Secretary Hamdallah Zedan remarked at the time that the fact that some 180 countries had already adopted them showed that parties wanted a clear authority guiding ABS issues. (IV)

The Bonn Guidelines recommend that each party designate one national focal point to handle ABS matters and that competent national authorities should be responsible for granting access and negotiating with users. (paragraphs 13, 14). While users are encouraged to seek prior informed consent and respect indigenous communities and customs, providers are instructed to avoid imposing arbitrary restrictions on access to genetic resources. (16(b), 16(c)(ii)). Paragraph 32 addresses *ex situ* collections, stating that "prior informed consent should be obtained from the competent national authority(ies) and/or the body governing the *ex situ* collection concerned as appropriate."

Appendix II lists possible monetary and non-monetary benefits that users can furnish providers. Benefits can include payments, fees, royalties, license fees, salaries, research funding, or joint ownership of IPR. Non-monetary benefits might include the sharing of research results, participation in product development, technology transfer, use of databases, contributions to the local economy, and enough other examples that users ought to be able to make a case that nearly anything is a "benefit."

Global Strategy for Plant Conservation (GSPC)

The Global Strategy for Plant Conservation (GSPCO was adopted in 2002 as the first specific conservation strategy developed under the CBD to serve as a pilot project for the CBD as well as a first step toward implementing the CBD's goals ("CBD" 2013). The GSPC's original goals included: 1. Documenting the plant diversity of the world; 2. Monitoring the status of plants and identifying those in need of protection; 3. Creating an integrated information system for the sharing of plant diversity information; 4. Promoting research on systematics, taxonomy, ecology, and conservation biology of plant communities; 5. Conserving plant diversity in-situ and, where necessary, ex-situ, preferably in countries of origin; 6. Using plant diversity sustainably; 7. Promoting education about plant diversity.

The world's leading botanic gardens immediately jumped on these tasks. The GSPC set ambitious goals for 2010: 60 percent of the world's threatened plant species conserved *in situ*, 60 percent of threatened plant species in accessible *ex situ* collections, with ten percent of those in recovery and restoration programs, and 70 percent of the genetic diversity of crops and other socio-economically valuable plants conserved ("CBD" 2013). Goals also included an accessible working list of all plant species, an assessment of the conservation status of all plant species, an end to threats to wild flora by international trade, preservation of plant resources and indigenous knowledge that support local food security and sustainability, the establishment or strengthening of networks of plant conservation at all levels, and more publicity and education about the importance of plant diversity (Wyse Jackson and Kennedy 2009).

These goals were easier stated than met. According to BGCI's 2010 survey of North American threatened plants, which considered 230 collections, only 39% of the 9,496 threatened taxa are grown in living collections or maintained as germplasm. Many of these holdings were themselves of questionable viability ("BGCI" 2013). Target two of the 2002 GSPC was a "preliminary assessment of the conservation status of all known plant species, at national, regional, and international levels." This was not accomplished by 2010, and has become a target for 2020. The other targets weren't reached either, though the garden community did make progress. The IUCN's conservation assessment process is too slow, and has provided assessments for fewer than 15,000 species. Though there are other systems for assessing conservation status, such as NatureServe, only the IUCN's system has been widely used for global conservation assessments. The IUCN's system doesn't really work well for plants, and regional assessments are not useful for global status (Miller et al. 2012).

Although the world's gardens had not met the GSPC's 2010 goals, the parties to the GSPC in 2010 created a new Global Strategy 2011-2020, intended to guide progress over the next decade. The Strategy's objectives include documenting and conserving plant diversity, using plants sustainably and equitably, and creating public awareness and engagement to protect plants ("CBD" 2013).

Targets include: 1. An online flora of all known plants; 2. Assessment of conservation status of all known plant species; 7. At least 75 percent of known threatened plant species conserved *in situ*; 8. At least 75 percent of threatened plant species in *ex situ* collections, preferably in their countries of origin, and at least 20 percent of threatened species in recovery and restoration programs; 11. No wild plants endangered by international trade; 13. Local and indigenous knowledge and practices maintained or increased; 14. Public education about the importance of plant diversity; 15 and 16. The cultivation of individuals, institutions, and networks to achieve these targets ("CBD" 2013).

Implementing the Strategy will require the cooperation of many institutions at international, national, regional, and local levels, including international organizations, communities, governments, universities and research institutions, and the private sector ("CBD" 2013). BGCI's recommendations for reaching the 2020 goal included better data sharing and collections management, stronger collaborative networks, and improved genetic diversity of collections ("BGCI" 2013). "Improved genetic diversity" means that gardens will have to collect more wild plants and exchange plants with one another.

Major botanic gardens are keenly interested in the CBD, both for its specific provisions on *in situ* and *ex situ* conservation and its controversial requirements for access and benefit sharing. According to Peter Wyse Jackson, the current director of the Missouri Botanical Garden, the international plant conservation scene had been transformed over the 1990s and 2000s with the adoption of the GSPC and the flurry of activity that followed it, especially among botanic gardens around the world (P. Wyse Jackson and Kennedy 2009).

WHAT ABS MEANS TO BOTANICAL GARDENS

Botanic gardens, arboreta, herbaria, and similar institutions must still gain access to wild plant material in order to develop their collections and fulfill their mission of documenting and conserving plant diversity. Gardens in most of the world must follow the CBD's guidelines on access and the sharing of benefits in order to develop their collections legally ("BGCI" 2013).

The CBD as an impediment to collection

A number of scholars in Europe and other parts of the world are worried that the CBD's ABS provisions actually impede scientific research by unreasonably restricting access to genetic resources in source countries. Criticisms include:

1. Biological resources are the common heritage of mankind and should not be subject to national ownership;
2. The CBD assumes that most uses of genetic resources are for highly profitable commercial endeavours;
3. The CBD has encouraged nations to pass laws that make the exchange of biological resources very difficult;
4. National regimes governing ABS are all very different from one another, making attempts to collect extremely complicated; and
5. The CBD fails to address the real causes of biodiversity loss, such as human population growth and development.

Some scholars believe that the fundamental assumptions behind the CBD were flawed. Martinez and Biber-Klemm (2010) argue that ABS regulations were written with commercial uses of biological materials in mind; host nations are keen to maximize the monetary benefits that can accrue from the use of genetic resources in products such as pharmaceuticals. Noncommercial research faces the same PIC requirements as commercial research, but academic researchers do not anticipate economic profits from their work. (There is also the simple matter that plants are living organisms, and do not themselves obey the CBD. Plants will readily spread on their own, even in captivity.)

Critics of the CBD suggest that state sovereignty over biological resources is inappropriate for resources that are actually the global commons or the common heritage of mankind (Zainol et al. 2011). Keui-Jung Ni pointed out in 2009 that prior to the adoption of the CBD, some scholars wanted to put genetic resources under international control to prevent resources from being dominated by sovereign nations. The thinking was that genetic resources are the common heritage of mankind and should therefore be available to all, not locked up in national legal regimes. The CBD took exactly the opposite approach, giving sovereign nations the right to monopolize the genetic resources that arise within their borders, and this approach has now taken on the form of customary international law (Ni 2009).

The intellectual property rights the CBD seeks to protect are not very common and in many cases are notional at best. It seems that many national ABS regimes envision biopiracy, or bioprospecting, or some complex project that will result in commercial products worth billions of dollars. The truth is that plant collection is not typically a profitable exercise. Gordon Cragg, a researcher with the Natural Products Branch of the National Cancer Institute, pointed out that between 1960 and 1982 the NCI studied 114,000 plant extracts from 13,000 different species, and produced exactly two drugs with commercial potential. As of late 2012, there were four other bioactive compounds isolated but not yet developed. It takes 20 to 30 years to develop a drug from a natural compound. A gold mine this is not (APGA Summit, October 2012).

Most bioprospecting happens in developing nations with rich biodiversity but lacking economic resources to exploit it. The CBD leaves the definition of prior informed consent up to the providing nation. Since the CBD was passed, many nations have been frustrated by developing nations' unwillingness to share their resources (Grebe 2011).

There is no consistent pattern of prior informed consent, and various nations have taken very different approaches to implementing ABS requirements. The notion of prior informed consent (PIC) comes from the medical principal that patients should agree to treatment after physicians disclose all relevant information, including all costs and benefits. PIC has been incorporated into international environmental law and the CBD, which requires that access to genetic resources be subject to prior informed consent of the party providing such resources. But the CBD does not address such issues as who is entitled to consent to access to genetic resources, the scope of the consent, and rights and obligations of those using and providing genetic resources. The CBD and the Bonn Guidelines both grant authority to enforce ABS to nations providing genetic resources (Ni 2009).

Rachelle Adam (2010) considered the reasons that biodiversity loss did not slow in the decade after the CBD was passed. She suggested that the CBD's initial assumptions, such as the assumption that compliance with multilateral environmental agreements could halt biodiversity loss, are mistaken. She believes that instead biodiversity is being lost partly because the world's nations to not agree that biodiversity needs to be protected. The United Nations Environmental Programme has said that failure to enforce multilateral environmental agreements is a leading cause of environmental degradation and that international environmental law should be one of the key elements of environmental protection. Adams points out that biodiversity is inevitably lost through ordinary human activities such as eating and living in homes, presenting what appear to be insurmountable obstacles to halting the process. She suggests that the CBD addresses the symptoms of biodiversity loss without getting at the root causes, such as population growth and failure of the market to reflect true environmental costs in prices, and recommends alternative approaches to halting the biodiversity crisis. (Adam 2010)

National ABS Regimes – a mixed bag

Developed nations tend to encourage strong plant monopoly rights – for example, the U.S. intellectual property regime gives precedence to breeders - but developing nations currently prefer to keep plant resources in the public domain, favoring traditional knowledge and farmer's rights. These nations often have long histories of local farmers freely cultivating local varieties, with a great deal of traditional knowledge behind geotypes. They have also had bad experiences or heard horror stories of companies acquiring intellectual property for plant life. The Pod-Ners "enola" bean incident, for example, involved a bean systematically bred by a U.S. farmer from a bag of beans purchased at a Mexican market. Farmers who had traditionally grown Mexican yellow beans found themselves suddenly forbidden to export the beans they had grown for generations. This sort of incident encourages developing nations to implement more restrictive laws regulating use of biological resources (Beck 2011).

Not every country has an ABS system in place, and in many places there seems to be some confusion as to exactly what needs to be done to apply for access. The various national authorities tasked with vetting applications may not understand the goals of scientific research and tend to be restrictive in their interpretation of applications. Strictly academic research can evolve into commercial research; countries do not want to risk allowing scientists to come explore their biota for academic reasons only to have that research turn into a profitable commercial enterprise down the road. Many nations feel that they have little reason to trust scientists and fear biopiracy. Even the act of scientific publishing might be against the interests of the providing country because information in the public domain ceases to be the providing country's intellectual property. This leads to very strict access regulations (Martinez and Biber-Klemm 2010).

Brazil, for example, has a notoriously onerous application process. Scientists who work there and their Brazilian collaborators must spend a great deal of time working through the bureaucracy, leading to a general feeling that the collection permit process does more harm than good to Brazil's biota. Brazil might actually be losing opportunities to get the help of foreign scientists who simply give up their plans for research. Costa Rica and Panama, on the other hand, have streamlined their permitting processes, which has led to greater knowledge of local biodiversity, increased international collaboration, and improved conservation (Antonelli and Rodriguez 2009).

Ni (2009) has found that there are currently two main genetic resource (GR) regulation models now: either a comprehensive biological diversity law that incorporates most of CBD, and access to GR is only part of the law, or a specific law covering management of GR only. India has the Indian Biological Diversity Act, which implements CBD requirements, but by ignoring the consent rights of local stakeholders and creating a National Biodiversity Authority that is responsible for regulating all access. Brazil as of 2009 had not created a national authority, still relying on a 2001 Provisional Measure that created a Council for the Management of Genetic Resources, though the states of Amapa and Acre had created their own state-level ABS legislation. Local stakeholders have a say, but the national authority makes all final decisions – which, as with India, has resulted in criticism that this adversely affects indigenous peoples. The Philippines in 1995 passed a law that gives extensive rights to indigenous peoples and local communities, which some applicants have found burdensome (Ni 2009).

Dr. Fernando Fernández of the Instituto de Ciencias Naturales at the National University of Colombia has recently complained that Colombia's national government has imposed a thicket of rules and restrictions that impede scientific research. Researchers must get permits for field work and museum exchanges, and they run the risk of having specimens confiscated by regional secretariats of the environment (Fernandez 2011).

F.M. Birhanu (2010), a law professor in Addis Ababa, has found that creating a national ABS regime is quite challenging for poor countries such as Ethiopia. First of all, he notes the CBD describes ABS in the most general of terms, leaving it up to individual countries to create regulatory schemes. Fifteen years after the CBD entered into force, very few African nations had passed ABS laws. Ethiopia, for example, has very high genetic diversity in food and cash crops, but until recently did not keep track of which of its genetic resources were taken out of the country. In 2006 the nation created an ABS Law, the Access to Genetic Resources and Community Knowledge and Community Rights Proclamation. The law is intended to ensure that the country and its communities get fair and equitable shares of benefits from resources. It applies to genetic resources both *in situ* and *ex situ*, including *ex situ* outside Ethiopia. Anyone who wants to access a genetic resource must get a written access permit from the Institute of Biodiversity Conservation and Research, a federal government institution. But the law does not require the federal government to consult regional or local governments, ABS agreements themselves are often poorly drafted, and there is little enforcement or follow-up on agreement (Birhanu 2010).

Many scholars believe that rather than being restrictive, states should realize that scientific research can offer many benefits to providing countries. Parties to the CBD are supposed to monitor their biodiversity, and basic research certainly contributes to that effort. However, many of the countries with the greatest needs have the least amount of capacity to accomplish this on their own. Taxonomic research in particular is essential to the cataloguing of biodiversity, and every nation needs non-national experts if it is to get a complete survey of its organisms. Overly restrictive access procedures benefit no one, including the providing nations that miss out on the benefits of scientific research on their biota (Martinez and Biber-Klemm 2010).

IMPROVING THE CBD

The parties to the CBD have been discussing refinements to the ABS system for the past decade. In 2008 the Barcode of Life initiative and other groups presented suggestions on ways to improve access for noncommercial research. The participants did not agree on a definition of noncommercial research, but they did agree that certain criteria distinguish noncommercial from commercial research. For example, noncommercial research results are placed in the public domain instead of being privately held, and noncommercial researchers do not file patents on their products. Going forward, Martinez and Biber-Klemm recommend that scientists participate more in ABS permit-granting committees, that the ABS system be adapted to accommodate noncommercial research, and that ABS application procedures be simplified. Academic researchers, for their part, can work to build trust by presenting transparent research goals and results and through cooperating with research partners in countries providing genetic resources. Unexpected discoveries that show commercial potential should be presented to providing countries for renegotiation of ABS agreements (Martinez and Biber-Klemm 2010).

Researchers want the ABS regime to include exemptions for genetic material procured exclusively for noncommercial academic research. One major question is whether the CBD should establish new ABS standards for scientific research or simply set minimum standards and allow researchers and countries to make agreement on a case-by-case basis. Scientists could certainly get more involved in the negotiation process, lobbying national governments, forming professional networks to participate, and attending CBD meetings as observers. Observer organizations are allowed to submit their opinions on specific issues to CBD conferences (Jinnah and Jungcurt 2009).

Some nations are considering various systems of certificates of origin, public documents that would certify the provenance of objects. Such a system could be voluntary or legally binding, or a combination of the two, and national offices entrusted with handling *ex situ* collections or plant breeding could take charge of the cases in their fields. An international searchable database of certificates of origin could vastly speed up the process of moving genetic material from place to place (Kraus and Rüssli 2011). The IPEN system already functions like this ("IPEN" 2013).

European scholars have been pondering the logistical difficulties of the CBD and publishing guides for researchers (see, e.g. Thornstrom and Bjork 2007). BGCI has prepared a fairly detailed manual for botanical gardens that must comply with the CBD (Davis 2008).

Nagoya Protocol

The Nagoya Protocol is a current effort to clarify ABS. The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity was adopted by the Conference of the Parties of the CBD in Nagoya, Japan, on October 29, 2010. It was open for signature by parties until 1 February 2012. By January 2013, 92 nations had signed the Nagoya Protocol and 11 had ratified it ("CBD" 2013).

The Nagoya Protocol attempts to refine the ABS provisions of the CBD. It creates provisions that emphasize a user nation's compliance with the laws and regulations of a nation providing genetic resources. The idea is to make sharing and access more predictable. The Protocol also strengthens provisions giving benefits to indigenous communities furnishing traditional knowledge and specifically invokes the role of women in these matters.

Of particular interest to scientists and Americans are the following provisions:

1. Article 8, Special Considerations, which calls on each party to encourage research that could lead to the conservation and sustainable use of biological diversity by simplifying access procedures for non-commercial research;
2. Article 14, which creates an Access and Benefit-sharing Clearing-House to share information on ABS provisions in various nations;
3. Article 17, which requires each party to monitor the use of genetic resources;

4. Article 23, Technology Transfer, Collaboration and Cooperation, which encourages parties to transfer technology and encourage technological growth in developing countries;
5. And Article 24, Non-Parties, which advises Parties to encourage Non-Parties to adhere to the protocol and contribute information to the ABS Clearing-House.

BGCI and European Response - IPEN

BGCI and its members have created principles on ABS for participating institutions; these principles are posted on the website of Royal Botanic Gardens, Kew. (http://www.kew.org/conservation/principles.html) Members promise to honor the letter and spirit of the CBD, CITES and other laws related to ABS and traditional knowledge. Anyone wishing to collect genetic resources must describe how they intend to use those resources and acquire PIC from the government of the country and other relevant stakeholders, including botanic garden management when acquiring resources from *ex situ* collections. Members are to create transparent policies on the commercialization of genetic resources acquired both before and after passage of the CBD. Written agreements are an important part of these transactions. Accurate curation and record-keeping is essential ("Royal Botanic Gardens, Kew" 2013).

In 2006 BGCI prepared materials on the CBD for those working with botanical collections to introduce them to the treaty and its requirements. These materials are available free at Kew's website both as a pdf file and as a Powerpoint presentation. The presentation lists some of the main ways in which botanical garden work is affected by the CBD: access to genetic resources, sustainable use, exchange of information and technology, identification and monitoring, etc. It explains that garden personnel must follow the national provisions regarding genetic material, particularly when gathering plants for garden collections. This is the case even in nations without post-CBD ABS legislation, such as most European nations, many of which had access procedures in place before the CBD was passed ("Royal Botanic Gardens, Kew" 2013).

Many European gardens belong to the International Plant Exchange Network (IPEN), an international network of 70 European botanic gardens designed to facilitate and regulate exchange of genetic materials among members ("IPEN" 2013). The IPEN requires its members to adhere to a code of conduct that governs acquisition and handling of living plant materials and benefit sharing. Gardens promise to accept only plant material acquired in accordance with the CBD. They agree to obtain PIC from countries of origin when collecting wild material. The documentation rules are quite strict, and materials distributed through the IPEN can be used only for non-commercial activities; if commercial uses of some plant material are contemplated, the garden must revisit the country of origin for a new PIC. Benefit-sharing can include joint expeditions, projects, and publications; reintroduction of threatened plant species to countries of origin; and exchange of technology and staff. This organization makes it very easy for members to exchange plant materials because all members use the same practices of documentation and ABS ("IPEN" 2013).

THE U.S. AND THE CBD

Although the U.S. is not a member of the CBD, with all other nations in the world participating in the regime it will inevitably feel the effects of the treaty. The NPGS Plant Exploration Program, for example, has found it much more difficult to collect plant materials as other nations have implemented ABS laws, and has given up on trying to get access to some nations with particularly restrictive or disorganized national regimes. The U.S. government recognizes the CBD as an international framework that ensures equitable sharing of access and benefits, and the State Department provides advice for compliance for researchers who want to collect genetic resources in other countries (Williams 2005).

Some U.S. botanic gardens and arboreta are adopting ABS provisions on their own. For example, in 2007 the National Tropical Botanical Garden in Coral Gables, FL, wrote its own policy on access to plant genetic resources and benefit-sharing ("NTBG" 2013). Fairchild Tropical Botanic Garden in Coral Gables has created its an Agreement to Supply Biological Material that complies with the CBD ("Fairchild Tropical Botanic Garden" 2013, "BGCI" 2013). The Missouri Botanical Garden created a Plant Genetic Resources Policy that guarantees that all plant genetic resources will be collected in compliance with international laws and regulations and recognizes that states have sovereignty over their genetic materials ("BGCI" 2013). MOBOT is committed to supporting the GSPC's 2011-2020 update and its 16 outcome-oriented global targets ("MOBOT" 2013).

APGA Summit

On October 24-26, 2012, the APGA and the National Arboretum held a summit to discuss the implications of the CBD to botanical gardens in the U.S. The organizers requested that I serve as a sort of respondent to kick off the afternoon discussions, summing up the content of the morning's presentations and setting the tone for the job du jour, which was to draft a code of conduct to help participating institutions comply with the CBD.

What became clear to me over the course of the summit was that there was no consensus on what the CBD means to U.S. institutions, what it requires, and how best to comply with its spirit. From a legal standpoint, the CBD doesn't apply to U.S. gardens. William Snape, an attorney who has written a fair amount on the CBD, pointed out that the convention does not have legal force in the U.S. and the U.S. is currently unlikely to ratify it. In any case, botanical gardens are not sovereign nations. Garden representatives are bound by national laws when acting on foreign soil, and they are allowed to enter into contracts with other parties regardless of the existence of the CBD.

Among garden representatives at the summit, there were some who espoused a very strict approach to tracking plant materials, and other who favored a freer approach to plant exchange. Andrew Wyatt of MOBOT, for example, described his garden's policies on plant sharing. MOBOT has adopted the CBD on an institutional basis, and is the only U.S. member of IPEN. All plant donations must have known provenance, and the garden will refuse donations that do not meet the correct criteria, particularly that plants be of documented wild origin. When a plant enters the collection, the curators record all material transfer agreements, which include restrictions on its use; each permit and other signed documents are stored in a file organized by date and collecting trip. All plants that leave the collection are tracked for compliance; each goes with records that tract prior informed consent, restrictions on use, material acquisition agreements. Recipients of plant materials must agree to abide by all restrictions on its use. MOBOT has placed IPEN numbers on all seed agreements. It will deny access to gardens that refuse to comply with its tracking procedures.

Chad Husby, of Montgomery Botanical Center, presented an opposing viewpoint. He pointed out that the past two decades have seen an emergence of hyperownership, a broadening of IP rights over living things and genetic materials. He described the current debate as a crossroads: U.S. gardens wishing to comply with the CBD could create a garden-level claim to perpetual ownership of genetic material through extremely broad MTAs and other restrictions, or they could abide by the ABS laws and MTAs of countries of origin but otherwise share plants as freely as possible. He compared the first approach to a plant prison, or genetic gulag, in which gardens will share materials but with heavy chains attached. He advocates instead following the approach of the USDA-NPGS, which shares resources freely and will not accept germplasm burdened with restrictions on its use.

Husby pointed out that sharing of plants is the original “benefit sharing.” People have shared plants for millennia, always allowing the free flow of resources. The growing of plants is itself a “benefit,” especially the propagation and growing of endangered plants from other nations. Public gardens bear the entire cost of this type of conservation. But ex situ conservation only works when plants are propagated and shared. The gulag approach prevents free propagation and sharing, and thus can endanger plants further. Husby recommended that U.S. gardens stop imposing Material Transfer Agreements (MTA) restrictions at the garden level, aside from excluding bioprospecting, and that they instead be bold and share the best benefits they have – expertise and plant materials.

That afternoon’s discussion focused on possible components of a code of conduct for APGA members wishing to comply with the CBD. Several things seemed clear to me:

1. Some participants assumed that the CBD has some legal force that applies to U.S. gardens, which is not the case.
2. Some larger gardens assume a level of standardization in curatorial practices that may not be the case across the board. In particular, there was a suggestion that gardens should standardize their inventories in BG-Base.
3. The suggested record-keeping and tracking of plant materials both before and after leaving the garden would require a great deal of time from a curator or similar employee.

As for the first point, it seemed to me that the participating gardens needed to clarify their relationship with the CBD before creating specific rules and guidelines to help gardens comply with it. Accordingly, I wrote the draft APGA Endorsement of the Principles of the Convention on Biological Diversity (Appendix E
APGA Endorsement of the Principles of the Convention on Biological Diversity, p.178). The draft included in this chapter has been through several revisions by participants, and as of January 2013 was in the hands of Pam Allenstein of the APGA.

And SCBG?

A small garden such as SCBG does not have the resources to track all details of plants after they leave the garden. Nor is it clear that this would benefit anyone.

Accordingly, I think it would be a mistake for the APGA to adopt any code of conduct of list of regulations that demands too much tracking of materials or use of any specific technology. That type of restriction would lock out institutions that lack financial and staffing resources as well as those that might be able to afford BG-Base or some extremely meticulous data-tracking system but simply do not believe that such things are correct for their garden and their work. There is no unanimous consensus that the philosophical basis of the CBD is correct, and in any case it does not apply either to the United States as a nation or to U.S. botanical gardens.

BGCI's recommendations for reaching the 2020 GSPC goals include better data sharing and collections management, stronger collaborative networks, and improved genetic diversity of collections. Implementing the Strategy will require the cooperation of many institutions at international, national, regional, and local levels, including international organizations, communities, governments, universities and research institutions, and the private sector ("CBD" 2013). A garden such as SCBG has a great deal to offer in the world of ex situ conservation and plant sharing – 290 acres can grow a lot of endangered species. It would be a loss to science and conservation to prevent it from participating in plant exchanges because it does not have the staff to keep up with voluminous paperwork.

CONCLUSION

It is worth looking again at some of the language of the CBD. Italics are mine.

Article 15. Access to Genetic Resources: "Each Contracting Party shall endeavour to create conditions *to facilitate access* to genetic resources for environmentally sound uses by other Contracting Parties *and not to impose restrictions* that run counter to the objectives of this Convention.

Article 16. Access to and Transfer of technology: "The Contracting Parties, recognizing that patents and other intellectual property rights may have an influence on the implementation of this Convention, shall cooperate in this regard subject to national legislation and international law in order to ensure that such rights are supportive of and do not run counter to its objectives."

Article 17. Exchange of Information: “The Contracting Parties shall *facilitate the exchange of information*, from all publicly available sources, relevant to the conservation and sustainable use of biological diversity, taking into account the special needs of developing countries.”

Note that the CBD calls for free exchanges – of information, of the results of research. It also calls for cooperation with national intellectual property regimes. But cooperating with national laws is one thing; imposing restrictions on our own institutions out of some sense of duty is another. Gardens that collect plants in other nations are by necessity bound by those nations laws, and by any private agreements they enter with other parties. That ought to be enough.

William J. Snape, Esq. (2010), of the Center for Biological Diversity, argues that the U.S. already has in place more of the CBD’s requirements – it has a system of protected areas, laws such as the Endangered Species Act, processes to oversee adverse impacts on biodiversity, and acknowledgement of tribal rights. The ABS provisions rely on parties’ freedom to contract and to mutually agree on terms, so no party will be forced into an agreement (Snape 2010). There are interesting new possibilities for intellectual property agreements. Open source licensing might work – in software they make code freely available, but users can’t then copyright their own work, thus maintaining a body of open material (Beck 2011).

In any case, U.S. gardens that wish to play on the international conservation field effectively belong to the CBD community anyway. Building trust with other nations is crucial. Individual gardens can form agreements with partners that observe currently expected standards of access and benefit sharing while avoiding unnecessary restrictions on research, propagation, and other activities. U.S. gardens might be in a pleasantly unique position to negotiate; because such gardens are not bound by the CBD, they could potentially have more access to genetic resources in other nations, especially in cases where the potential for commercial profit is obviously low. The new openness and sharing of information might lead to new opportunities and collaborations, and ultimately to more effective conservation of biodiversity.

Ultimately, the CBD attempts to facilitate the sharing of materials and information to conserve biodiversity. The primary reason to share access and benefits is to ensure that genetic resources and the benefits they confer on humans are available to as wide a range of institutions and individuals as possible. Selfishness will ultimately prove counterproductive to botanical gardens' conservation efforts.

CHAPTER 6 – LOOKING TO THE FUTURE

The SCBG has made tremendous changes in just two and a half years, the time I have spent working on my doctorate.

1. It has adopted a coherent collections philosophy, which the director is applying to current and future collections-building.
2. It has created a database and inventory system that allows rapid in-the-field updating of records and mapping.
3. It has installed a new collection of native plants in naturalistic ecological settings in the Natural Heritage Garden.
4. It has integrated undergraduate teaching into collections-building and garden design.
5. It has explored citizen science initiatives using students to collect data for a national project.
6. It has joined a national conservation network and explored joining another.
7. It has pursued a collaboration with other institutions to publish heretofore inaccessible historical data and to interpret that data, using resources unique to Clemson (i.e. expertise on South Carolina botany).
8. It has participated in a national debate on international conservation policy.
9. It is using its collections to collect scientific data (e.g., field trialing seed-grown *Shortia galacifolia*.)

With its data management in order, SCBG is in a good position to clean up its data and maintain that data in good condition. This will make it possible to use that data for scientific research in the future.

A curator of living collections would be a good addition to the staff. The director of the garden should be able to concentrate on overall design and outreach; a curator could handle the administrative and management aspects of collection building and maintenance, including data management and sharing with other institutions.

In the future, SCBG should continue to pursue multi-institutional collaborations, through the APGA, the CBP, BGCI, the NAPCC, and other institutions. While it may not currently have the resources to maintain and monitor a large collection of endangered plants, it might in the future, as more plants become endangered and the value of *ex situ* conservation becomes more apparent. Making those connections will place it in a good position to pursue this work.

Other tasks for the near future could include:

1. Place database online. Garden users would benefit from being able to search for individual plants.
2. Match up historical records and herbarium specimens with current inventory.
3. More use of undergraduate classes to build collections.
4. Expanding research in the garden with other faculty members.

5. Using tissue culture and other resources to expand collections of endangered plants.
6. Continue to work on Botanica Carolinina, analyzing the other materials we collected in London, and adding collections such as André Michaux’s plants.
7. Continued collaboration with Furman University through grants from the IMLS or NSF.
8. Continued discussion with botanical garden community on implications of Convention on Biological Diversity to gardens and to scientific research in general.

SCBG is not wealthy and it does not have a huge staff. Those are limitations, to be sure, but this project shows that a garden that looks beyond its limitations and maximizes its strengths can do a great deal. It is a matter of making the most of available resources. Efficiency, technology, energy and creativity can make it possible for a small garden such as SCBG to make a real contribution to the botanical garden world.

APPENDICES

APPENDIX A: SCBG POLICIES

SCBG Living Collections Policy

Introduction

The South Carolina Botanical Garden (SCBG) is a 295-acre garden owned by the state of South Carolina and attached to the campus of Clemson University, a land-grant institution. It is home to a extensive collection of native and cultivated plants and includes a 70-acre aboretum, and numerous habitats ranging from forestland to bog to meadow. The SCBG's living collections should fit within the three prongs of Clemson's mission as a land-grant institution: research, education, and outreach.

Mission and Goals of the Living Collection at the SCBG

The SCBG's living collections exist to provide an educational resource for the general public, provide a basis for exchange of information among researchers at Clemson and with other institutions, preserve endangered plants, and provide enjoyment to visitors. The goals of the SCBG include demonstrating horticultural leadership through providing habitats and planned gardens that are suitable to and exemplary of Clemson's bioregion; serving as a repository for federally endangered species; collecting, evaluating, and introducing taxa with ornamental and/or cultural merit; and housing nationally recognized collections of specific taxa including *Magnolia*, *Ilex*, *Acer*, and *Hydrangea*. These objectives correspond with the goals of botanic gardens worldwide, which exist to hold permanent or semi-permanent collections of plants with some scientific basis; to monitor and document those plants; to engage in scientific or horticultural research on plants in living collections and herbaria; to exchange seeds, plant materials, and information with other institutions; and to educate members of the general public who visit the garden.

Purpose of Living Collections Policy

This policy is intended to guide the SCBG in the development and maintenance of current and future living collections, including the determination of plants that should be accessioned or deaccessioned. The Living Collections Policy is written and administered by the Living Collections Committee, which includes the Garden Director, and the Horticulture Staff at the SCBG (Senior Horticulturalist, Grounds Manager, Nursery Manager).

Acquisitions

All new plant material acquired by the SCBG must meet specific collections development goals in accordance with this Living Collections Policy. Acquisitions can come through purchase, gift, exchange with other institutions, or through field collection.

Ethical and Legal Considerations

The SCBG complies with all relevant local, state, national, and international laws guiding the collection and distribution of living plants. The SCBG evaluates all accessions for invasiveness and, does not introduce new collections deemed to be a threat to local ecosystems. If the scientific or educational value of a particular invasive taxon already in the collection justifies its cultivation, the SCBG takes all necessary steps to ensure that the species does not spread outside the pre-determined boundaries allotted to it within the SCBG.

Living Collections Categories

The living collections of the SCBG are divided into three primary categories with different levels of priority. By prioritizing collection goals, the SCBG can best decide how to allocate resources including money, space, and staff time.

Core Collections

The core collections are the SCBG's top priority. These collections are most essential to the SCBG's research, education, and outreach missions. These collections are obligatory.

Southeastern Natives Collection

One of the SCBG's main goals is the cultivation of local plant taxa in order to preserve local species and educate visitors about plants that grow in South Carolina. To this end, the SCBG makes its collections of local plants a top priority. The living collections include plants materials of both cultivated and wild origin, though the preservation of wild-originated plant material takes precedence over that of cultivated plants. In developing these collections, the SCBG requires that new accessions be of known and well-documented provenance.

Conservation Collections

The SCBG is committed to preserving plants that are endangered in the wild by growing them in its living collections, thus serving as a repository for federally endangered species. The SCBG cooperates with the USDA Forest Service, the USFWS and actively seeks associations with organizations such as the North American Plant Collections Consortium (NAPCC) and the Center for Plant Conservation (CPC). Any living collection that the SCBG maintains as part of a commitment to such an organization is a top priority of the garden. In its role as a national germplasm repository for endangered taxa, the SCBG attempts to preserve as high a level of intraspecific genetic diversity as possible.

Historic and Horticultural Collections

The SCBG originated in 1958 as a test site for cultivated Camellias. Since that time a number of Clemson faculty members and horticulturists have installed plants that have horticultural and historical value. These gardens include the Camellia Trail, the Dwarf Conifer Garden, the Hydrangea Garden, the Shoeneke Arboretum, the Hosta Garden, the Specialty Arboretum, and others. The SCBG also houses plants undergoing trials for suitability for the horticultural marketplace.

Although the SCBG may lack information on the provenance of these plants and not all of the plants are accessioned, many of them may represent material unique in cultivation or material of other historical value such as cultivar introductions. Because many of these plants many represent unique genotypes, they are worth maintaining. These collections may be obligatory or discretionary, as determined by the Living Collections Committee.

Educational Collections

The SCBG contains a number of gardens developed specifically to educate the public on various aspects of botany and horticulture. These gardens include the Childrens' Garden, the Xeriscape Garden, the Cherokee Worldview Garden, and several others. This category also includes natural areas, such as the Hopkins Beech Grove and the Wildflower Meadow.

These gardens are important to the SCBG's outreach and education missions. Although the plants grown in these gardens may or may not be accessioned, they are considered part of the living collections. These plants may be obligatory or discretionary. Development and maintenance of these collections is determined on a case-by-case basis by the Living Collections Committee.

Definitions

1. **Accession**: the basic unit of the collection, comprising either a single plant or group of plants of the same taxon, identified by a unique accession number.
2. **Accessioning**: the process of adding a specimen to the collection at the time of the plant's arrival at the SCBG, including identifying the specimen with a unique accession number. These records should be permanent; a specimen's accession record will not be deleted should that specimen be deaccessioned.

3. **Collection**: a group of accessions organized according to a specific category. A single accession can belong to more than one collection. The members of a collection need not be physically grouped together.
4. **Deaccessioning**: removing a living specimen from a collection. The specimen's record will be maintained.
5. **Development**: the building of collections through acquisition of new specimens and deaccessioning of specimens that no longer meet the SCBG's collections goals.
6. **Discretionary**: describes collections and accessions that are not central to the SCBG's mission and that therefore can be temporary.
7. **Maintenance**: the process of vegetatively propagating an accession to preserve its genetic lineage. Individual plants produced by this process will be genetically identical.
8. **Obligatory**: describes collections and accessions that are central to the SCBG's mission and that are therefore permanent and maintained.
9. **Taxon**: a unit of rank within a taxonomic hierarchy, such as species or family.

SOUTH CAROLINA BOTANICAL GARDEN DISASTER PLAN

Annual Planning – Setting Priorities

The staff should meet at least once a year to discuss disaster preparedness and update the disaster plan.

Possible Hazards

The Upstate area faces several types of natural disasters on a near-annual basis. Storms that down trees and branches are the most common threat in this area.

1. High winds – hurricanes, tornadoes, thunderstorms, mostly summer and early fall
2. Ice Storms – typically December through February
3. Other less likely disasters – fires, earthquakes, bomb threats

Prioritize Collections

The Living Collections Policy prioritizes plants according to their conservation, historical, and educational values. Plants should be protected in the following order:

1. High conservation value and good provenance
2. High conservation value but poor provenance
3. Historic collections
4. Display/educational collections

The Garden must balance the cost of replacing plants against the cost of protecting them. In many cases, replacing specimens will be the cheaper and more effective option.

Garden Security

Good garden maintenance and curation will make handling disasters easier.

1. Maintain health of plants, remove dead branches
2. Keep inventory and map up to date
3. Propagate important and rare plants from cuttings as “backups”
4. Back up database off-site
5. Keep list of campus and city/county emergency contacts

Before Disaster – Preparation

Many disasters are predicted before they arrive, affording time to take protective action.

1. Identify type of disaster and likely damage
2. Decide which plants to protect.
3. Site-specific actions – sandbags, cover against cold, shelters, move plants, secure/board up offices, turn off water
4. Order fuel delivery and fuel up vehicles
5. Take cuttings, collect seeds from high-conservation-value plants; secure off-site
6. Secure computers, equipment – get important things out of trailer, remove to safe location
7. Assign responsibilities
8. Share contact lists
9. Send employees home before disaster strikes
10. Communicate with campus security

During Disaster

Number one priority – staff and visitor safety.

1. Most likely hazards: falling branches and trees, falling power lines.
2. If trees are flying around, stay away!
3. Wait for notification from campus security that the area is safe to enter.
4. If conditions are safe and the benefit is clear, consider remedial actions such as sandbagging.

After Disaster – Clean-up and Repair

Contact staff to make sure everyone is safe; call meeting

Triage

Have a quick meeting to decide what to do first (only AFTER downed power lines are rendered safe and no more trees are falling).

1. Emergency work – chainsaws, clearing roads, removing immediate hazards
2. Quick inventory – note which high-priority plants are destroyed, damaged
3. Propagation materials – take cuttings from important downed specimens; place in baggie, label with sharpie, get into cooler or to nursery ASAP
4. Data – take notes on all actions on paper, ipad, other device; update database when possible
5. Team meeting at end of day – summarize progress, identify next steps

6. Who can help? Volunteers, student workers, local responders

Repairing the Collections

Display gardens without conservation value can probably be repaired fastest, important for attracting visitors. Historic and conservation collections may be more difficult to repair.

1. Display gardens – reopen as quickly as possible, find new seasonal and bedding plants
2. Historic collections – can historic specimens be replaced with same types?
3. Conservation collections – propagate, update as feasible
4. Can the damage become part of the display as a portrayal of natural succession?

APPENDIX B: SCBG ACCESSION PROCEDURE

Every plant that enters the SCBG's collection must be accessioned. This is the process of giving the plant a unique identifier called an accession number, and entering its information into the garden's database. Accessioning allows the garden to keep track of the plants in its collection and makes it possible for the garden to participate in scientific research and conservation initiatives.

Accessioning

All new accessions must fit into one of the categories in the Living Collections Policy.

Arrival

All new arrivals will undergo the following accessioning procedure:

1. Receive new plants in the nursery. All new plants must remain on the nursery mat until they have been accessioned.
2. Evaluate the plant for appropriateness and invasiveness. No invasive exotics will be accessioned.
3. After a plant is approved for accessioning, record its data on the appropriate form. The plant's location in the database will initially be "Nursery Mat".
4. Enter the data for each new accession in the computerized inventory. The computer will automatically generate an accession record for each new accession.

5. Print an accession tag and affix it to the new plant. This tag will remain on the plant at all times.
6. Ornamental plantings don't need to be accessioned. When in doubt about a new plant, consult the Director.

Planting

When it is time to plant a new accession, or to move a plant from one location to another, follow this procedure:

1. Print a permanent ground tag.
2. Transport the plant to its new location and plant it.
3. Ensure that the accession tag is clearly visible.
4. Insert the ground tag in the appropriate place.
5. Take GPS coordinates of the plant in its new location.
6. Enter the new location data and planting date in the database.

Deaccessioning

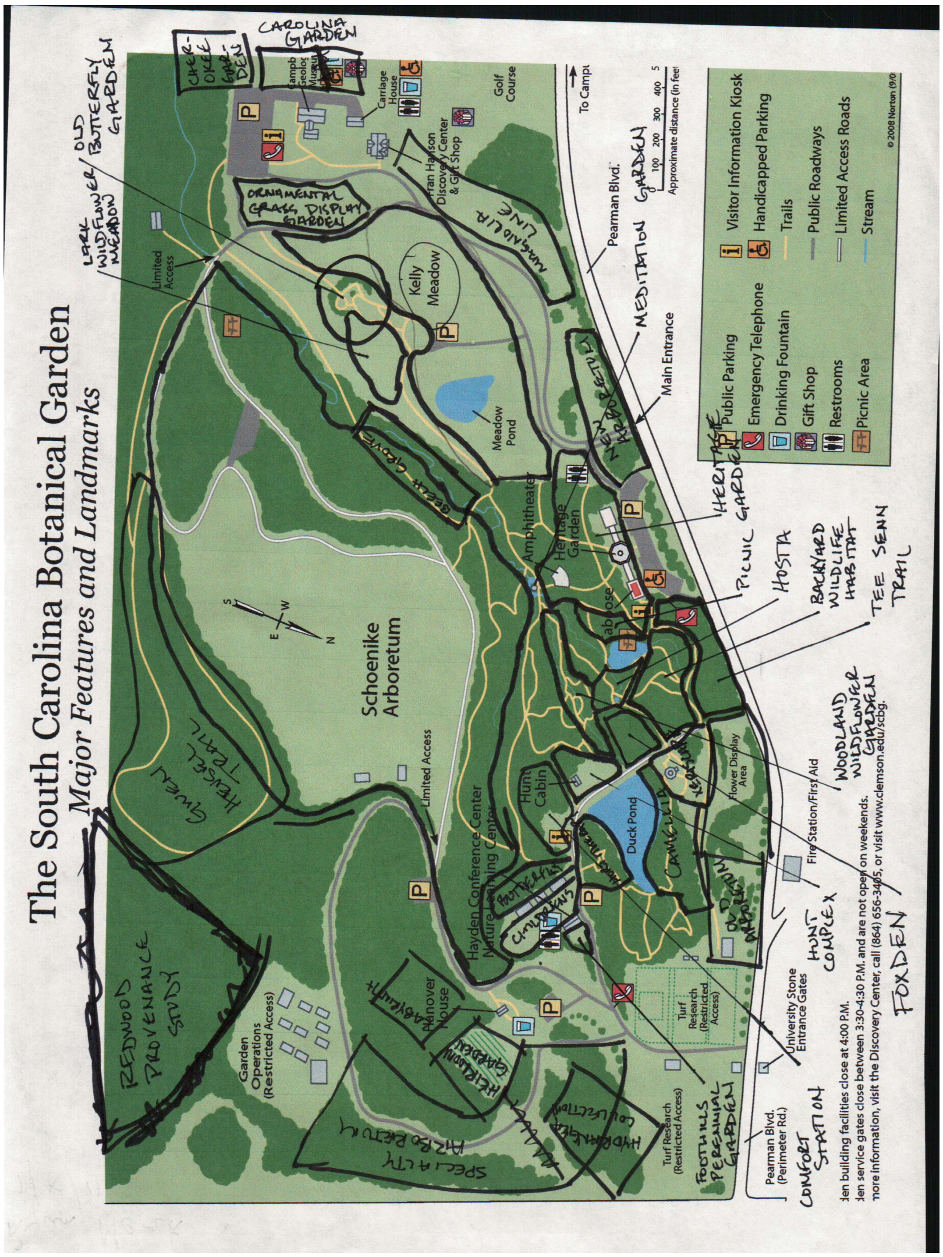
Deaccessioning is as important as accessioning. When plants die or are removed from the collection, the garden must record this information in its inventory.

1. Record the plant's death on appropriate form.
2. Remove the accession tag from the plant and the ground tag from the ground.
3. Place the accession tag in the "Dead" bucket.

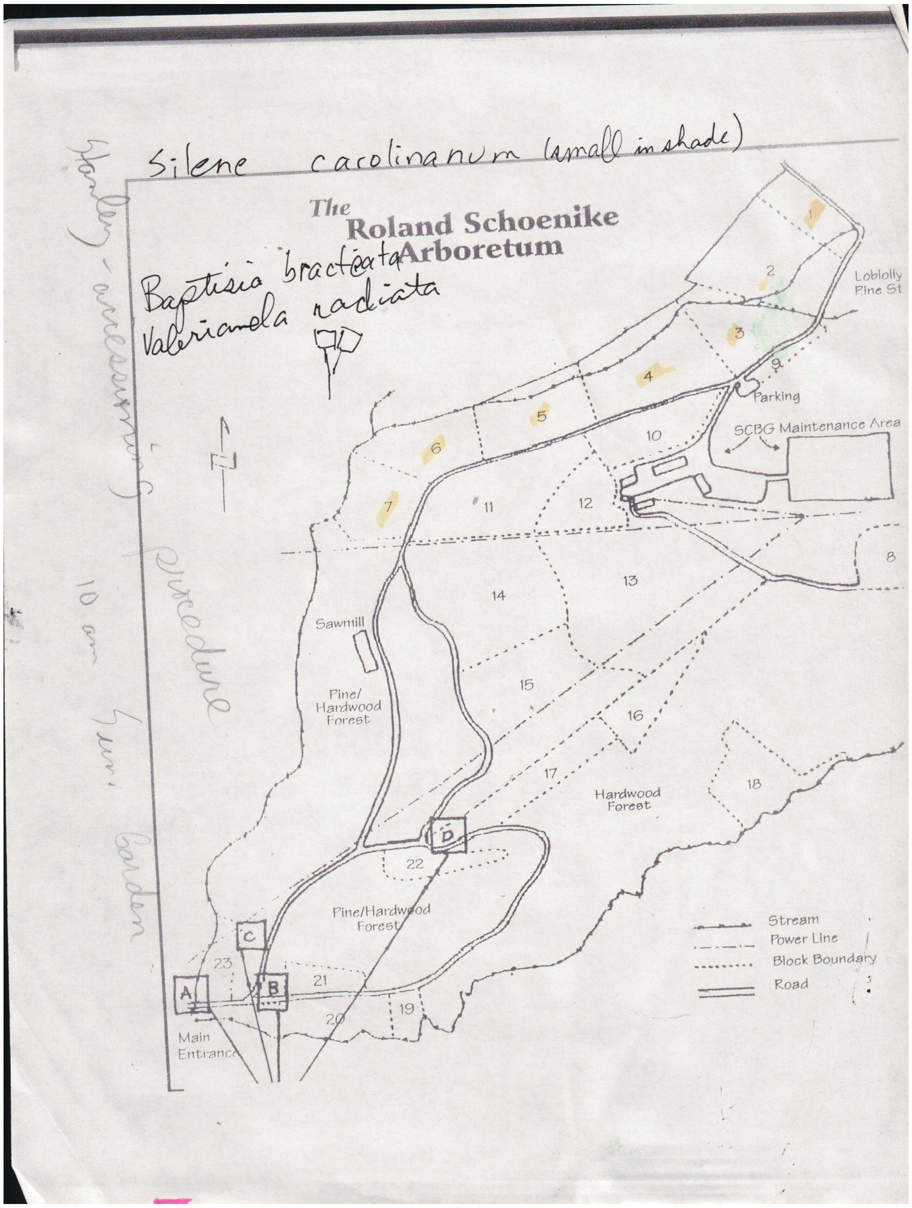
4. Change the plant's status to "dead" in the database. Update any relevant information. Once a plant has been recorded as "dead", it is permissible to dispose of its accession tag.
5. Remove the plant from its location according to appropriate practices (digging up, cutting down).

APPENDIX C: MAPS

C.1: Map, South Carolina Botanical Garden, Annotated



C.2: MAp, Shoenike Arboretum



APPENDIX D: MAGNOLIAS

D.2 Magnolias, January 2010

This is the list of magnolias that the garden manager assembled in January 2010, which constituted the basis of the NAPCC's interest in SCBG's collection and its value to the multi-institutional magnolia conservation group.

Accession Number	Scientific Name	Garden Location	Plant Status	Date Inventoried
710150	Magnolia acuminata	2 B 9	Good	12/4/2009
710151	Magnolia acuminata	2 C 10	Good	12/4/2009
7365	Magnolia cavaleriei var. platypetala	Specialty Arboretum	Good	2/24/2006
990282	Magnolia chapensis (formly Michelia)	Specialty Arboretum	Good	11/2/2009
970192	Magnolia denudata	6 P 3	Good	12/4/2009
7368	Magnolia ernestii (syn. M. wilsonii)	Specialty Arboretum	Good	11/2/2009
7369	Magnolia ernestii (syn. M. wilsonii)	Specialty Arboretum	Good	11/2/2009
7370	Magnolia ernestii (syn. M. wilsonii)	Specialty Arboretum	Good	2/24/2006
7376	Magnolia ernestii (syn. M. wilsonii)	Specialty Arboretum	Good	2/24/2006
940198	Magnolia figo (formly Michelia)	Specialty Arboretum	Excellen t	11/2/2009
750011	Magnolia figo (formly Michelia)	2 B 8	Good	12/4/2009
820070	Magnolia figo (formly Michelia)	15 J 12	Good	12/4/2009
690034	Magnolia figo (formly Michelia)	15 M 5	Good	12/4/2009
9218	Magnolia figo (formly Michelia)	Plant Sale Garden	Good	12/8/2009
9219	Magnolia figo (formly Michelia)	Plant Sale Garden	Good	12/8/2009
9220	Magnolia figo (formly Michelia)	Plant Sale Garden	Good	12/8/2009
9332	Magnolia figo (formly Michelia)	Xeriscape Garden	Good	12/8/2009
992866	Magnolia figo Port Wine (formly Michelia)	Specialty Arboretum	Fair	11/2/2009
810046	Magnolia fraseri	2 D 10	Good	12/4/2009
790027	Magnolia fraseri	4 Z 3	Good	12/4/2009
840023	Magnolia grandiflora	3 N 11	Good	12/4/2009
610043	Magnolia grandiflora	4 T 11	Good	12/4/2009
590043	Magnolia grandiflora	11 P 16	Good	12/4/2009
7828	Magnolia grandiflora	Specialty Arboretum	Good	8/20/2008
9359	Magnolia grandiflora	Hayden Center Garden	Good	12/8/2009
7631	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Excellen t	7/31/2008
9226	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9227	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9228	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9229	Magnolia grandiflora Brackens Brown	John W. Kelly Meadow	Good	12/8/2009

	Beauty			
9230	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9234	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9235	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9236	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9237	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9238	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9239	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9240	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9241	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9242	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9243	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9244	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9245	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9246	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9247	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9248	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9249	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9250	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9251	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9252	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9253	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9254	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9255	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9256	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9257	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9258	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9259	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9260	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9261	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9262	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009

9263	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9264	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9265	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9266	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9267	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9268	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9269	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9270	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9271	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9272	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9273	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9274	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9275	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9276	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9277	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9278	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9279	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9280	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9281	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9282	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9283	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9284	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9285	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9286	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9287	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9288	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9289	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9290	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9291	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9292	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9293	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009

9294	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9295	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9296	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9297	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9298	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9299	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9300	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9301	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9302	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9303	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9304	Magnolia grandiflora Brackens Brown Beauty	John W. Kelly Meadow	Good	12/8/2009
9305	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9306	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9307	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9308	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9309	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9310	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9311	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9312	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9313	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9314	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9315	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9316	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9317	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9318	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9319	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9320	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9321	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9322	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9323	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009
9324	Magnolia grandiflora Brackens Brown Beauty	Specialty Arboretum	Good	12/8/2009

9335	Magnolia grandiflora Brackens Brown Beauty	Caboose-Display Walkway	Good	12/8/2009
9343	Magnolia grandiflora Brackens Brown Beauty	Display Garden	Good	12/8/2009
9344	Magnolia grandiflora Brackens Brown Beauty	Display Garden	Good	12/8/2009
9345	Magnolia grandiflora Brackens Brown Beauty	Display Garden	Good	12/8/2009
9347	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9348	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9349	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9350	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9351	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9352	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9353	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9354	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9355	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9356	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
9357	Magnolia grandiflora Brackens Brown Beauty	Garden Trail Service Entrance	Good	12/8/2009
981910	Magnolia grandiflora Parris Select	Specialty Arboretum	Good	10/6/2009
42995	Magnolia grandiflora Teddy Bear	Shoenike Arboretum	Excellent	12/4/2009
42997	Magnolia grandiflora Teddy Bear	Shoenike Arboretum	Excellent	12/4/2009
8580	Magnolia grandiflora Timeless Beauty	Specialty Arboretum	Good	11/6/2009
740027	Magnolia heptapeta	4 Z 2	Good	12/4/2009
990849	Magnolia insignis (formly Manglietia insignis)	Specialty Arboretum	Fair	11/2/2009
9210	Magnolia insignis (formly Manglietia insignis)	Fox Den	Good	12/8/2009
9211	Magnolia insignis (formly Manglietia insignis)	Fox Den	Good	12/8/2009
9212	Magnolia insignis (formly Manglietia insignis)	Fox Den	Good	12/8/2009
9213	Magnolia insignis (formly Manglietia insignis)	Plant Sale Garden	Good	12/8/2009
730025	Magnolia kobus	2 J 8	Good	12/4/2009
710152	Magnolia kobus	3 C 4	Excellent	12/4/2009
710153	Magnolia kobus	3 D 1	Excellent	12/4/2009
710154	Magnolia kobus	3 D 2	Excellent	12/4/2009
720061	Magnolia kobus	5 F 2	Good	12/4/2009
680061	Magnolia kobus	11 P 4		12/4/2009
990028	Magnolia laevifolia (formly Michelia yunnanensis)	Specialty Arboretum	Good	11/2/2009
7362	Magnolia laevifolia (formly Michelia yunnanensis)	Specialty Arboretum	Good	2/24/2006

7363	Magnolia laevifolia (formly Michelia yunnanensis)	Specialty Arboretum	Good	2/24/2006
7364	Magnolia laevifolia (formly Michelia yunnanensis)	Specialty Arboretum	Good	2/24/2006
7613	Magnolia laevifolia (formly Michelia yunnanensis)	Specialty Arboretum	Good	3/26/2008
9341	Magnolia laevifolia (formly Michelia yunnanensis)	Hortitherapy Garden	Good	12/8/2009
710155	Magnolia liliiflora	15 T 25	Good	12/4/2009
620089	Magnolia liliiflora Nigra	11 O 6	Good	12/4/2009
700067	Magnolia liliiflora Nigra	14 E 15	Good	12/4/2009
700068	Magnolia liliiflora Nigra	14 E 16	Good	12/4/2009
620086	Magnolia macrophylla	6 F 14	Good	12/4/2009
660035	Magnolia macrophylla	11 M 2	Good	12/4/2009
620087	Magnolia macrophylla	20 D 6	Good	12/4/2009
880131	Magnolia macrophylla	20 F 6	Good	12/4/2009
840021	Magnolia macrophylla var. ashei (formally M. ashei)	3 M 8	Good	12/4/2009
840022	Magnolia macrophylla var. ashei (formally M. ashei)	3 N 10	Good	12/4/2009
7620	Magnolia maudiae (formly Michelia maudiae)	Specialty Arboretum	Good	3/26/2008
7621	Magnolia maudiae (formly Michelia maudiae)	Specialty Arboretum	Good	3/26/2008
7622	Magnolia maudiae (formly Michelia maudiae)	Specialty Arboretum	Good	3/26/2008
7624	Magnolia maudiae (formly Michelia maudiae)	Hayden Center Garden	Good	3/26/2008
7625	Magnolia maudiae (formly Michelia maudiae)	Specialty Arboretum	Good	3/26/2008
7627	Magnolia maudiae (formly Michelia maudiae)	Shoenike Arboretum	Good	3/26/2008
9330	Magnolia maudiae (formly Michelia maudiae)	Picnic Garden	Good	12/8/2009
9331	Magnolia maudiae (formly Michelia maudiae)	Picnic Garden	Good	12/8/2009
720059	Magnolia obovata (formally M. hypoleuca)	2 C 5	Good	12/4/2009
720060	Magnolia obovata (formally M. hypoleuca)	2 C 8	Good	12/4/2009
9214	Magnolia odora	Hydrangea Collection	Fair	12/8/2009
990816	Magnolia platypetala (formly Michelia)	Specialty Arboretum	Good	11/2/2009
7366	Magnolia platypetala (formly Michelia)	Specialty Arboretum	Good	2/24/2006
7367	Magnolia platypetala (formly Michelia)	Specialty Arboretum	Good	11/2/2009
7623	Magnolia platypetala (formly Michelia)	Specialty Arboretum	Good	3/26/2008
7628	Magnolia platypetala (formly Michelia)	Specialty Arboretum	Good	3/26/2008
7630	Magnolia platypetala (formly Michelia)	Xeriscape Garden	Good	3/26/2008
67114	Magnolia salicifolia	4 K 1	Good	12/4/2009
710156	Magnolia sprengeri Diva	2 D 8	Poor	12/4/2009
660038	Magnolia stellata (syn. M. kobus var. stellata)	11 P 1	Good	12/4/2009
660039	Magnolia stellata (syn. M. kobus var. stellata)	11 P 2	Good	12/4/2009
9338	Magnolia stellata (syn. M. kobus var. stellata)	Old Arboretum Collection	Good	12/8/2009
9339	Magnolia stellata (syn. M. kobus var. stellata)	Hortitherapy Garden	Good	12/8/2009
9340	Magnolia stellata (syn. M. kobus var.	Hortitherapy Garden	Good	12/8/2009

	stellata)			
9342	Magnolia stellata (syn. M. kobus var. stellata)	Hortitherapy Garden	Good	12/8/2009
32941	Magnolia stellata Waterlily (syn. M. kobus var. stellata Waterlily)	Shoenike Arboretum	Excellent	12/4/2009
690033	Magnolia tripetala	3 A 5	Excellent	12/4/2009
800061	Magnolia tripetala	7 J 3	Good	12/4/2009
9143	Magnolia tripetala	Cherokee Garden	Fair	12/2/2009
9327	Magnolia tripetala	Wildlife Habitat	Good	12/8/2009
9328	Magnolia tripetala	Wildlife Habitat	Good	12/8/2009
9329	Magnolia tripetala	Wildlife Habitat	Good	12/8/2009
610044	Magnolia virginiana	11 N 7	Good	12/4/2009
610045	Magnolia virginiana	11 O 9	Good	12/4/2009
981452	Magnolia virginiana	11 P 18	Good	12/4/2009
970372	Magnolia virginiana Coosa	16 D 12	Good	12/4/2009
9209	Magnolia virginiana Coosa	Xeriscape Garden	Good	12/8/2009
9215	Magnolia virginiana Henry Hicks	Plant Sale Garden	Poor	12/8/2009
9216	Magnolia virginiana Henry Hicks	Plant Sale Garden	Poor	12/8/2009
990358	Magnolia virginiana Tensaw		Good	12/4/2009
9204	Magnolia virginiana Wilson (Moonglow)	Perimeter Road	Good	12/8/2009
9205	Magnolia virginiana Wilson (Moonglow)	Perimeter Road	Good	12/8/2009
9206	Magnolia virginiana Wilson (Moonglow)	Perimeter Road	Good	12/8/2009
9207	Magnolia virginiana Wilson (Moonglow)	Hanover House Garden	Good	12/8/2009
9208	Magnolia virginiana Wilson (Moonglow)	Hanover House Garden	Good	12/8/2009
990191	Magnolia x brooklynensis Woodsman	Hosta Garden	Good	12/4/2009
8501	Magnolia x Elizabeth	Hayden Center Garden	Good	11/18/2008
8503	Magnolia x Elizabeth	4 Z 2	Good	11/18/2008
9325	Magnolia x Elizabeth	John W. Kelly Meadow	Good	12/8/2009
9326	Magnolia x Elizabeth	Picnic Garden	Good	12/8/2009
9217	Magnolia x foggii (formly Michelia)	Plant Sale Garden	Good	12/8/2009
9333	Magnolia x loebneri Super Star (syn. M. kobus var. loebneri Super Star)	Xeriscape Garden	Good	12/8/2009
9334	Magnolia x loebneri Super Star (syn. M. kobus var. loebneri Super Star)	Caboose-Display Walkway	Good	12/8/2009
960529	Magnolia x skinneriana	Specialty Arboretum	Excellent	11/2/2009
6627	Magnolia x skinneriana	Heritage Garden	Good	12/4/2009
9221	Magnolia x skinneriana	Plant Sale Garden	Good	12/8/2009
9222	Magnolia x skinneriana	Plant Sale Garden	Good	12/8/2009
9223	Magnolia x skinneriana	Plant Sale Garden	Good	12/8/2009
9224	Magnolia x skinneriana	Plant Sale Garden	Good	12/8/2009
9225	Magnolia x skinneriana	Plant Sale Garden	Good	12/8/2009
9336	Magnolia x soulangeana Alexandriana	Old Arboretum Collection	Good	12/8/2009
9337	Magnolia x soulangiana	Old Arboretum Collection	Good	12/8/2009
8514	Magnolia yuyuanensis	Hydrangea Collection	Good	12/1/2008
11863	Magnolia zenii	Specialty Arboretum	Good	10/6/2009
8804	Magnolia zenii	Shoenike Arboretum	Good	3/4/2009

D.1 Magnolias, September 2011

This is the list of magnolias we presented to the NAPCC outside examiner, Frank Telewski, when he visited SCBG to assess the site and the collection. The data is still incomplete. I inserted GPS coordinates for every tree I could find. A number of accessions lack GPS coordinates; these are trees that I was unable to locate.

Accession Number	Genus	Species	Garden Location	Longitude	Latitude
710150	Magnolia	acuminata	2 B 9	-82.818835	34.67466833
710151	Magnolia	acuminata	Shoenike Arboretum		
10249	Magnolia	acuminata		-82.81737972	34.67580472
2011-0224	Magnolia	acuminata	cherokee garden		
10738	Magnolia	amoena	Operation Facility's Nursery		
7364	Magnolia	cavaleriei	Specialty Arboretum	-82.81810333	34.67638667
990816	Magnolia	cavaleriei var. platypetala	Specialty Arboretum	-82.81616139	34.67451333
7365	Magnolia	cavaleriei var. platypetala		-82.81811333	34.676455
7366	Magnolia	cavaleriei var. platypetala	Specialty Arboretum		
7367	Magnolia	cavaleriei var. platypetala	Specialty Arboretum	-82.81686472	34.67369
7623	Magnolia	cavaleriei var. platypetala	Specialty Arboretum		
7628	Magnolia	cavaleriei var. platypetala	Specialty Arboretum		
7630	Magnolia	cavaleriei var. platypetala	Xeriscape Garden		
990282	Magnolia	chapensis	Specialty Arboretum	-82.81698167	34.67449167
7363	Magnolia	conifera	Specialty Arboretum		
10392	Magnolia	cylindrica		-82.81994667	34.67352667
740027	Magnolia	denudata (formally heptapeta	4 Z 2		
970192	Magnolia	denudata (formally heptapeta	6 P 3	-82.822525	34.67284667
990025	Magnolia	ernestii (formallly Michelia wilsonii)	Specialty Arboretum		
7368	Magnolia	ernestii (formallly Michelia wilsonii)	Specialty Arboretum		
7369	Magnolia	ernestii (formallly Michelia wilsonii)	Specialty Arboretum		
7370	Magnolia	ernestii (formallly Michelia wilsonii)	Specialty Arboretum		
940198	Magnolia	figo	Specialty Arboretum	-82.81706667	34.67446667
750011	Magnolia	figo	2 B 8	-82.81858833	34.67465167

820070	Magnolia	figo	15 J 12		
690034	Magnolia	figo	15 M 5		
992866	Magnolia	figo	Specialty Arboretum	-82.81577972	34.67438167
9218	Magnolia	figo	Plant Sale Garden		
9219	Magnolia	figo	Plant Sale Garden		
9220	Magnolia	figo	Plant Sale Garden		
9332	Magnolia	figo	Xeriscape Garden		
2011-0228	Magnolia	figo	plant sale garden		
960529	Magnolia	figo var. skinneriana	Specialty Arboretum	-82.81701472	34.67448
960922	Magnolia	figo var. skinneriana			
990623	Magnolia	figo var. skinneriana			
6627	Magnolia	figo var. skinneriana	Heritage Garden		
9221	Magnolia	figo var. skinneriana	Plant Sale Garden		
9222	Magnolia	figo var. skinneriana	Plant Sale Garden		
9223	Magnolia	figo var. skinneriana	Plant Sale Garden		
9224	Magnolia	figo var. skinneriana	Plant Sale Garden		
9225	Magnolia	figo var. skinneriana	Plant Sale Garden	-82.817605	34.673345
960302	Magnolia	foveolata	Unknown		
2011-0096	Magnolia	foveolata	Nursery Mat		
810046	Magnolia	fraseri	2 D 10	-82.81873833	34.67461833
790027	Magnolia	fraseri	4 Z 3	-82.8209	34.67344333
990849	Magnolia	insignis	Specialty Arboretum	-82.81592806	34.67450333
9210	Magnolia	insignis	Fox Den	-82.82210167	34.67484833
9211	Magnolia	insignis	Fox Den	-82.82205833	34.67495167
9212	Magnolia	insignis	Fox Den	-82.82205833	34.67495167
9213	Magnolia	insignis	Plant Sale Garden	-82.817605	34.673345
730025	Magnolia	kobus	2 J 8	-82.81887667	34.67419167
710152	Magnolia	kobus	3 C 4	-82.81880167	34.67404833
710153	Magnolia	kobus	3 D 1	-82.81884	34.67405833
710154	Magnolia	kobus	3 D 2	-82.81876667	34.67402833
720061	Magnolia	kobus	5 F 2		
680061	Magnolia	kobus	11 P 4		
990028	Magnolia	laevifolia	Specialty Arboretum	-82.81698167	34.67448667
7362	Magnolia	laevifolia	Specialty Arboretum		
7613	Magnolia	laevifolia	Specialty Arboretum	-82.81742972	34.67678333
9341	Magnolia	laevifolia	Hortitherapy Garden		
620089	Magnolia	liliiflora	11 O 6		
700067	Magnolia	liliiflora	14 E 15	-82.82222667	34.67183972
700068	Magnolia	liliiflora	14 E 16	-82.82246667	34.67179667
710155	Magnolia	liliiflora	15 T 25		
990029	Magnolia	lotungensis			
990819	Magnolia	lotungensis	Specialty Arboretum		
990820	Magnolia	lotungensis			

990821	Magnolia	lotungensis		-82.81594139	34.67446167
992024	Magnolia	lotungensis	Specialty Arboretum		
620086	Magnolia	macrophylla	6 F 14		
660035	Magnolia	macrophylla	11 M 2	-82.82211667	34.67242
620087	Magnolia	macrophylla	20 D 6		
880131	Magnolia	macrophylla	20 F 6		
10516	Magnolia	macrophylla		-82.81715972	34.67565833
10734	Magnolia	macrophylla	John W. Kelly Meadow	-82.82492667	34.66854972
2011-0225	Magnolia	macrophylla	backyard wildlife		
2011-0227	Magnolia	macrophylla	plant sale garden		
2011-0229	Magnolia	macrophylla	woodland wildflower garden		
840021	Magnolia	macrophylla var. ashei	3 M 8	-82.81945472	34.67405472
840022	Magnolia	macrophylla var. ashei	3 N 10	-82.81964	34.67413833
7620	Magnolia	maudiae	Specialty Arboretum	-82.81721833	34.67606333
7621	Magnolia	maudiae	Specialty Arboretum		
7622	Magnolia	maudiae	Specialty Arboretum	-82.817925	34.67651167
7624	Magnolia	maudiae	Hayden Center Garden	-82.81872333	34.67546333
7625	Magnolia	maudiae	Specialty Arboretum		
7627	Magnolia	maudiae	Shoenike Arboretum	-82.82253333	34.67267333
9330	Magnolia	maudiae	Picnic Garden		
9331	Magnolia	maudiae	Picnic Garden		
720059	Magnolia	obovata	2 C 5	-82.818495	34.67472667
720060	Magnolia	obovata	2 C 8	-82.81850167	34.67477333
9214	Magnolia	odora	Hydrangea Collection	-82.81866472	34.67445833
2011-0061	Magnolia	officinalis	Schoenike block 7		
990024	Magnolia	salicifolia			
67114	Magnolia	salicifolia	Shoenike Arboretum		
10461	Magnolia	salicifolia	4 K 1	-82.81978333	34.67364833
2011-0060	Magnolia	salicifolia			
710156	Magnolia	sprengeri	2 D 8	-82.81850167	34.67477333
950061	Magnolia	stellata	Unknown		
960171	Magnolia	stellata			
950033	Magnolia	stellata	Operation Facility's Nursery		
660038	Magnolia	stellata	11 P 1		
660039	Magnolia	stellata	11 P 2	-82.82241667	34.672195
990364	Magnolia	stellata			
32940	Magnolia	stellata			
32941	Magnolia	stellata	Shoenike Arboretum		
9339	Magnolia	stellata	Hortitherapy Garden	-82.82019	34.67484667
9340	Magnolia	stellata	Hortitherapy Garden	-82.81944333	34.67525833
9342	Magnolia	stellata	Hortitherapy Garden	-82.82015	34.67517333
9358	Magnolia	stellata	Hortitherapy Garden		
2011-0230	Magnolia	stellata	near spittin' image		
690033	Magnolia	tripetala	3 A 5	-82.81855333	34.67412667
800061	Magnolia	tripetala	7 J 3		

9143	Magnolia	tripetala	Cherokee Garden		
9327	Magnolia	tripetala	Wildlife Habitat		
9328	Magnolia	tripetala	Wildlife Habitat		
9329	Magnolia	tripetala	Wildlife Habitat	-82.82218333	34.67466333
2011-0235	Magnolia	tripetala	backyard wildlife		
2011-0236	Magnolia	tripetala	backyard wildlife		
2011-0231	Magnolia	virginiana	magnolia line		
920258	Magnolia	virginiana var. australis	Operation Facility's Nursery		
610044	Magnolia	virginiana var. australis	11 N 7	-82.82221972	34.67261
610045	Magnolia	virginiana var. australis	11 O 9	-82.82225667	34.67262667
970372	Magnolia	virginiana var. australis	16 D 12	-82.82070167	34.67024472
981452	Magnolia	virginiana var. australis	11 P 18	-82.82222833	34.672645
990355	Magnolia	virginiana var. australis			
990357	Magnolia	virginiana var. australis			
990358	Magnolia	virginiana var. australis		-82.82059833	34.670305
990359	Magnolia	virginiana var. australis			
22057	Magnolia	virginiana var. australis	Operation Facility's Nursery		
6546	Magnolia	virginiana var. australis			
6547	Magnolia	virginiana var. australis			
32492	Magnolia	virginiana var. australis	Operation Facility's Nursery		
9204	Magnolia	virginiana var. australis	Perimeter Road	-82.82021333	34.67692
9205	Magnolia	virginiana var. australis	Perimeter Road	-82.819255	34.67744167
9206	Magnolia	virginiana var. australis	Perimeter Road	-82.81944333	34.67736833
9207	Magnolia	virginiana var. australis	Hanover House Garden		
9208	Magnolia	virginiana var. australis	Hanover House Garden		
9209	Magnolia	virginiana var. australis	Xeriscape Garden		
9215	Magnolia	virginiana var. australis	Plant Sale Garden	-82.81757167	34.67352833
9216	Magnolia	virginiana var. australis	Plant Sale Garden	-82.817605	34.673345
9360	Magnolia	virginiana var. australis		-82.82283972	34.67460333
9361	Magnolia	virginiana var. australis	BC Geology Museum Garden		
9362	Magnolia	virginiana var. australis	BC Geology Museum Garden		
9363	Magnolia	virginiana var. australis	Discovery Center		
960236	Magnolia	x	Wildlife Habitat		
1077	Magnolia	x	John W. Kelly	-82.82440833	34.66854667

			Meadow		
8501	Magnolia	x	Hayden Center Garden	-82.81909667	34.67535833
8503	Magnolia	x	4 Z 2	-82.82083833	34.67333833
9325	Magnolia	x	John W. Kelly Meadow	-82.82682833	34.67083833
9326	Magnolia	x	Picnic Garden	-82.82343167	34.67419167
9337	Magnolia	x	Old Arboretum Collection	-82.820965	34.67612167
9338	Magnolia	x	Old Arboretum Collection	-82.82109333	34.67612667
10318	Magnolia	x	Discovery Center		
2011-0086	Magnolia	x	Display		
2011-0232	Magnolia	x	magnolia line		
2011-0233	Magnolia	x	magnolia line		
990191	Magnolia	x brooklynensis	Hosta Garden	-82.82290472	34.67469167
992867	Magnolia	x foggii #2			
974	Magnolia	x foggii #2	Specialty Arboretum		
5304	Magnolia	x foggii #2			
32178	Magnolia	x foggii #2			
9217	Magnolia	x foggii #2	Plant Sale Garden		
2011-0234	Magnolia	x foggii #2	specialty arboretum		
990023	Magnolia	x kewensis			
960235	Magnolia	x loebneri			
970193	Magnolia	x loebneri			
9333	Magnolia	x loebneri	Xeriscape Garden		
9334	Magnolia	x loebneri	Caboose-Display Walkway		
9336	Magnolia	x soulangeana	Old Arboretum Collection	-82.82116833	34.67620972
2011-0223	Magnolia	x soulangeana	museum		
8514	Magnolia	yuyuanensis	Hydrangea Collection	-82.81775833	34.67653667
2011-0221	Magnolia	yuyuanensis			
11863	Magnolia	zenii	Specialty Arboretum	-82.817635	34.67564333
8804	Magnolia	zenii	Shoenike Arboretum	-82.81962167	34.67399472
990808	Manglietia	chingii			
990809	Manglietia	chingii			
990810	Manglietia	chingii			
990811	Manglietia	chingii			
32234	Manglietia	fordiana			
11749	Manglietia	insignis			
970593	Manglietia	moto			
950072	Michelia	maudiae		-82.81652	34.67436972
990027	Michelia	sinensis			
981040	Michelia	x			
991307	Michelia	x	Specialty Arboretum		
940145	Michelia	x foggii		-82.81712833	34.67442667

APPENDIX E

APGA ENDORSEMENT OF THE PRINCIPLES OF THE CONVENTION ON BIOLOGICAL DIVERSITY

The APGA member gardens enthusiastically support the objectives of the Convention on Biological Diversity (CBD): conservation of biological diversity, sustainable use, and fair and equitable sharing of the benefits arising from utilization of genetic resources.

The CBD is an international convention between member nations. Gardens are not sovereign nations. Thus, gardens are not parties to the convention. Nevertheless, public gardens already contribute to CBD objectives and can help advance and shape those objectives as the Convention becomes more fully implemented.

Gardens are essential to *ex situ* conservation of biological diversity, research on plants for recovery and rehabilitation of threatened species and their reintroduction into natural habitats (CBD Article 9). Gardens **are** the *ex situ* collections described in the CBD's Global Strategy for Plant Conservation Target 8, tasked with conserving at least 75 percent of threatened plant species by 2020. The conservation, study, and propagation of endangered plant species is one of the biggest benefits gardens offer the world.

Gardens establish and maintain education and training programs in identification, conservation and sustainable use of biological diversity (CBD Article 12). Gardens promote and encourage understanding of the importance of the conservation of biological diversity and cooperate with other organizations to develop education and public awareness programs. (CBD Article 13)

Gardens abide by legal requirements and restrictions of countries regarding access to plants. Gardens also build partnerships and share benefits with our international partners. (CBD Article 15)

Gardens accept the CBD’s recommendation to exchange technology and information, and to engage in technical and scientific cooperation among institutions using the biological resources in our collections and among institutions and nations that have granted our member gardens access to their genetic resources. (CBD Article 16, 17, 18)

One of the APGA’s greatest strengths is the diversity of its member gardens, each of which makes unique contributions to serve their public. Each individual institution is free to create its own policies governing access to and use of its collections, with the understanding that each will strive to facilitate access to the genetic resources in those collections.

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